RF Project 2508

Final Report

THE OHIO STATE UNIVERSITY

RESEARCH FOUNDATION

1314 KINNEAR ROAD COLUMBUS, OHIO 43212

GEOMORPHOLOGY AND PEDOLOGY OF AMCHITKA ISLAND

K. R. Everett

Department of Agronomy
and
Institute of Polar Studies

September 1969

GEOMORPHOLOGY AND PEDOLOGY OF AMCHITKA ISLAND

FINAL REPORT

K.R. Everett

Department of Agronomy
and
Institute of Polar Studies

The Ohio State University
Columbus, Ohio 43210

Prepared for Battelle Memorial Institute

September 1969

CONTENTS

FIGURES

TABLES

PLATES

SUMMARY

Amchitka Island is composed of volcanic rocks and minor amounts of sandstones, conglomerates and glacial deposits, all of relatively recent geologic age. Most of these rocks are fractured and faulted. The Island has undergone a series of upward and downward movements relative to sea level. Much of the present topography of the Island has been conditioned by its past positions relative to sea level, as well as by glacial and near-glacial climatic conditions.

Geomorphically the Island can be separated into six more or less distinct segments. The three eastern segments are characterized by upland areas with numerous shallow lakes and ponds with little or no drainage connection. On both the north and south sides of the upland the land surface is dissected into low hills. The drainage between ponds may be both via surface and subsurface routes. The streams reach the sea across an elevated marine platform after exiting through deep "V"-shaped valleys. With the exception of the shallow organic cover of the easternmost segment, this area is covered with 20 to 40 inches or more of organic soil.

Elevations rise westward across the third segment of the Island. Lakes become less numerous, drainage is more integrated and active natural erosion, especially wind erosion, becomes more obvious. The organic soil mat is severely abraded in many places, and landslides, especially along steep coastal bluffs, and slumping in the headward areas of streams, are common.

In the mountainous segment V of the Island, absolute and relative relief are at a maximum, as is erosion. The thick organic soils give way to easily fluidized mineral soils; mass-movement expresses itself in the form of hillside terraces, solifluction lobes, and surface wash in the higher areas. A more-normal but more sandy organic soil sequence occurs at lower elevations.

Westward of the mountainous segment is a plateau area with many characteristics of the eastern segments. However, the number of lakes is small; the organic soil mat resembles that in segments IV and V.

Seven distinct soil types have been identified on the basis of their drainage, moisture content, character of peat, particle size distribution of underlying mineral soil, position in the landscape, and natural stability. Their field relationships are presented on 5 map sheets which accompany this report.

These soil groups have been mapped in detail at small scale and form the basis for predictions as to their behavior under testing and construction activities. The soil characterizations provide a basis on which the biological programs, particularly vegetation and pond ecology studies, can draw for community distribution and pond chemistry.

Soils designated a_1 occur in broad stream valleys, shallow swales and former pond areas. Areally they are among the least significant of any group. They are composed of coarse fibrous peat which exceeds 40 inches in depth and overlies silty or silty clay mineral soil. Moisture contents commonly exceed 1000% on an oven dry basis. These soils are naturally stable but will undergo subsidence if drained. Soils designated a_2 are somewhat better drained than a_1 soils and occur on level to slightly sloping terrain. They are composed of coarsely to moderately fibrous peat and have moisture contents between 500% and 800%. Because of a thin gelatinous layer beneath the vegetation, they are very susceptible to vehicular traffic damage, especially when the surface is wet. Their natural stability is high. These soils in combination with a_1 soils cover large areas of the poorly drained upland flats.

Slightly better drained slopes whose angle ranges between 3° and 33° support group b soils. These soils are of variable thickness, ranging between 20 and 70 inches or more and are composed of more thoroughly decomposed organic matter than either groups a_1 or a_2. Group bh soils lie upslope of group b soils. They occur on hummocky, vegetation covered slopes (2-15°). Many of these slopes are active solifluction sheets. Thickness is quite uniform, averaging 20 inches. These soils are composed of well humified organic matter which is usually fractured or jointed. Group bh along with group b soils are naturally rather stable but both can be involved in slumping along stream channels or on very steep bluffs. Sliding most frequently takes place at the organic matter-mineral soil contact. In group bh soils water movement and probably some drilling fluid movement takes place both through the fractured organic matter and along the organic matter-mineral soil contact.

Group c soils occur on crest areas and are usually associated with wind erosion. They are well drained and have only a thin organic horizon. Where eroded, the organic material is absent, and they are designated as soil group ce. These soils are relatively instable, but are most resistant to vehicular damage. Their natural instability is expressed in landslides and solifluction lobes and terraces.

Soils of groups h and e comprise only minor units. Those of group h have developed on stabilized block fields near summit areas in physiographic segment V. Group e soils are well-drained and sandy, developed on stabilized dune areas along north facing coastal bluffs. Sandy places of all soil groups have been recognized from physiographic units III through VI.

Off-road vehicular traffic and construction activities pose the greatest threat to the organic soil cover of Amchitka Island. Disruption of the organic mat, especially slippage of bh and b soils on slopes and adjacent to streams can be anticipated for several miles of ground zero. The amount of coastal sliding and seacliff destruction will depend upon the test site considered. Test site B should present no real problems. Subsidence after testing may seriously affect the ground water table and cause irreversible changes in the organic mat, i.e., compaction and drying. The reaction of the different types of soil organic matter to the uptake and release of radio-nucleides deposited as a result of particulate venting should be considered. The attached table, duplicated from the test presents a physical assessment of the different soil groups and their probable reaction to testing and test related activities.

INTRODUCTION

Pedologic and geomorphic work was conducted on Amchitka Island during the summers of 1967 and 1968. The objectives of this investigation, for which this is the final report, were as follows:

1. To integrate a study of soil stability and soil characterization with ground shock predictions which would lead to predictions of the probable extent of mass movement and alterations in soil conditions;
2. To delimit the potentially shock-sensitive soils and the physical characteristics which contribute to their sensitivity;
3. To formulate a list of critical soil characteristics which will have both long and short-term predictive value for the behavior of the different soil groups associated with testing and construction and for reclamation of disturbed areas. Both the 1967 and 1968 field work centered largely on a characterization of the major soil types and their distribution. Once the range in soil types had been defined, a program of selective sampling was undertaken. A sufficient number of soil profiles were described and sampled to assure soil characterization representative of the soil type. This area also provided a check on the validity and areal distribution of the different types. In conjunction with morphological descriptions for each soil type, quantitative estimates were made on the natural stability of the particular soils in relation to their topographic setting.

Selected, representative profiles were analyzed chemically and physically. These analyses not only provide further verification of the distinctiveness of soil types described in the field, but also will provide information on soil genesis which can be related to other and similar soils described elsewhere in the Aleutian Chain.

The majority of the soils of the Island are organic. The organic material ranges widely in structure and composition between soil groups as well as regularly within a single soil type. Such variations assume particular importance in regard to drainage, moisture transmission and trafficability.

In April 1968 two movement grids of 16 stakes each were set and surveyed. Both grids are in areas of natural slope instability involving several soil types.

Physical Geography

Amchitka Island, a member of the Rat Island group, lies between 178°37' and 179°29' east longitude. The Island is one of the most southerly of the Aleutian Islands, lying between 51°21' and 51°39' north latitude, or at approximately the same latitude as northern Vancouver Island, British Columbia. Amchitka Island is approximately 40 miles long trending in a northwest direction. The Island width ranges between one and five miles, but averages generally less than 3.5 miles.

Geology

The rocks of Amchitka Island are in general of andesitic composition. Powers *et al.* (1960) have recognized four major formations. The oldest, the Amchitka Formation of Tertiary age, consists of volcanic agglomerates, tuff breccias, and pillow lavas which have been deformed and jointed. These rocks crop out in an area extending from a few miles northwest of Constantine Harbor to about one mile southeast of South Bight, and in small areas near Cyril Cove, Chitka Cove, and along a six-mile segment of the north coast between Chitka Cove and Bird Cape.

The largest proportion of the Island is composed of the Tertiary Banjo Point Formation and the Tertiary-Quaternary Chitka Point Formation. The Banjo Point Formation crops out from St. Markarius Point to a position 3.5 miles northwest of Banjo Point, where it lies in fault contact with the Chitka Point Formation. It is composed of sandstone, conglomerate, tuffaceous shales, and basaltic tuff. It is highly faulted.

The Chitka Point Formation underlies the remainder of the Island westward to Aleut Point. It is composed of flows and flow breccias of porphyritic andesite interbedded with marine conglomerates. This formation, like the others, is cut by numerous major and minor faults.

Other rocks on the Island include dikes, sills, and a small stock of quartz diorite on the extreme east end of the Island, and glacial and interglacial deposits in the Constantine Harbor and South Bight grabens.

As far as this report is concerned, only the Amchitka, Banjo Point, and Chitka Point Formations are important. Of these, the

Banjo Point Formation underlies the bulk of the soils described.

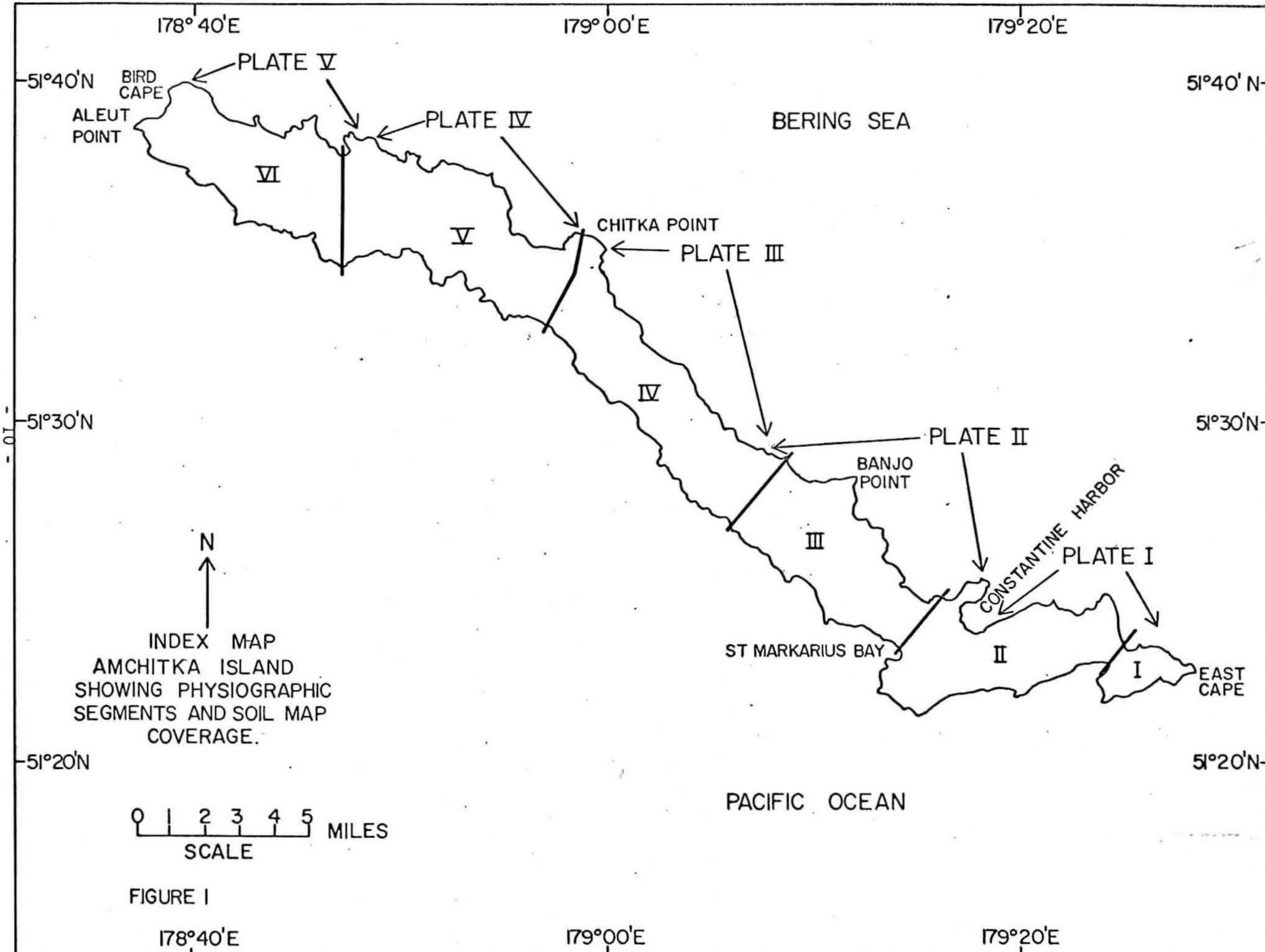
Climate

Powers _et_ _al._ (1960) cite arctic weather central (1950) data which indicate that Amchitka Island has a maritime climate with small seasonal and daily temperature variations. The mean annual temperature between 1943 and 1948 was 4.4°C with extremes between -9.5°C and +18.4°C. During the summer months, fog occurred more than 50% of the time and complete overcast more than 65% of the time. Precipitation during the measurement period averaged 35 inches annually, and snowfall 70 inches. Much of the rainfall occurs as light intermittent showers with occasional periods of heavy rain. Wind velocity averaged about 20 miles per hour.

Physiography

Amchitka Island can be divided into six rather distinct geomorphic units or segments, (Figure 1). The landforms of each segment are to some extent conditioned by the underlying bedrock. Most are relics of recent geomorphic processes rather than the products of current processes.

Physiographic segment I consists of the easternmost 2 miles of the Island. The south coast is one of low relief and grades from a low, slightly emergent wave plained rock shelf across a nearly level, very poorly drained raised platform to a well defined sea cliff and second platform at the extreme east end (about 1 mile west from East Cape). Both platforms are broad. The lower platform consists



INDEX MAP
AMCHITKA ISLAND
SHOWING PHYSIOGRAPHIC
SEGMENTS AND SOIL MAP
COVERAGE.

FIGURE I

of East Cape itself and has a shallow cover of peat over bedrock and cobbles. The distribution of driftwood indicates that Tsunamis frequently sweep the area. The second platform contains numerous shallow lakes, and may actually be a very shallow basin. The soils are somewhat better drained but thin, usually less than 8 inches of organic material over bedrocks or more commonly wave rounded quartz diorite boulders, many of which protrude through the organic mat. Although lakes are numerous, drained and vegetation covered former lakes suggest that at one time in the not too distant past the number of lakes was much more extensive.

A thick sea cliff rises to a flat to slightly depressed upland. This sea cliff is more dissected than the lower one. The organic soils are thicker and show a wider range in drainage characteristics. Numerous lakes occur on the upland and soils are for the most part thin and poorly drained.

Although the south coast generally displays a very recent wave cut platform the north coast terminates in abrupt cliffs which rise vertically from 35-40 feet from the sea. The lower most marine platform appears to be missing. The Quartz diorite bedrock displays a prominent NE joint set with a crossing set at nearly 45°. Strong wave action has eroded embayments and Tsunami generated waves have torn bedrock blocks from the walls and thrown them along with driftwood and large blocks of organic soil, as much as 150 feet inland. There is no indication that this phenomenon is frequent, although when it occurs the erosive force is great.

The lack of integration of the drainage on the second platform, the shallow transitional nature of the soil cover, the rather poor expression of vegetation sequences, the lack of solifluction forms and the shallow rock-floored lakes combine to suggest that this area of the Island has been above sea-level only a short time, probably since the last periglacial period.

This segment of the Island is separated from the next by the South Bight Graben.

Physiographic segment II extends from the South Bight Graben westward to Constantine Harbor. It is underlain by the Amchitka Formation and has a nearly complete blanket of mosses, lichens, sedges, and low heath which mantle the low, rounded bedrock hills. Numerous small lakes and ponds dot the terrain, both on the relatively flat central portion of this segment, and in depressions surrounded by the low hills. Most of the individual ponds drain from one to the other by small, perennial streams which flow through most of their course in subsurface channels. Many of these channels have no surface expression other than a dry, shallow, vegetation covered depression. The subsurface stream flow can be seen where circular or oblong sections of the super-stream or false valley have collapsed, producing a "karst-like"* valley (Figure 2). The drainage on the north side of the Island segment debauches onto a relatively level, discontinuous, emerged marine platform through deep "V"-shaped valleys. The marine platform* is generally absent on the south side

* See glossary, Appendix C

Figure 2: Karst-like valley and sink holes in organic terrain, physiographic segment 2, Amchitka Island.

or only poorly expressed. Here the streams enter the sea directly through narrow, deep canyons. In either case the streams head within a mile of the flat, poorly drained central portion of the segment. It seems likely, as Powers et al. (1960) suggest, that the central portion of the segment represents an uplifted, plained surface. In this segment it is probably equivalent to the third surface in Segment I. Subsequent to uplift, stream erosion rather thoroughly dissected the margins, producing a hilly topography. The marine platform so well exposed on the north coast may have been cut at this time. Subsequently the marine platform has been uplifted and a new one is being cut. Since that time stream activity and erosion have been negligible. On the south coast where streams enter the sea directly, headward erosion seems to be continuing at a more rapid pace.

One of the most characteristic morphologic elements to be found on the Island are conical, vegetation-covered peat mounds which occur in great abundance on the upland surface of this segment. They and similar features occur in lesser abundance in segments III and IV. The mounds commonly occur in groups or fields. Individually they range in height from 3 to 6 feet and have base diameters from 3 to 10 feet. Shacklette (Personal Communication) recognizes several genetically different forms. Although similar mounds occur on other Island segments, most of the larger ones on the western part of the Island appear to have a rock core and owe their vegetation cover to fertilization by roosting sea birds. Those in Segment II are composed entirely of organic material, much of it in a relatively undecomposed state. The internal composition of a typical mound is shown in Figure 3.

In many cases the large conical features occur in association with tussock tundra, i.e., small tussocks of vegetation and peat which rise 12-15 inches above the surrounding peat or mineral soil. The lack of pattern in the distribution of the larger features and their structural similarity to the tussocks suggests a random, self-perpetuating and limiting process closely associated with drainage hanges induced by peat accumulation are responsible for the large mounds.

The tussock areas are similar to those in northern Alaska, although composed of different vegetation. Several large areas of this type appear as a separate map unit on the soils map composed of an association of bh soils. Excavation across both tussocks and depression, Figure 4, suggests that on flat terrain the hummocks reflect a sorted net pattern developed during a colder climate just prior to the initiation of the peat. The depressed borders of the nets containing the coarser rocks and sand are somewhat better drained and more stable than the raised, finer grained inner portions. This facilitates the accumulation of the vegetation and organic matter in the depressions. Eventually this accumulation results in a topographic reversal with hummocks concentrated at net intersections. The passage of time and buildup of the hummocks has served to obliterate the original pattern.

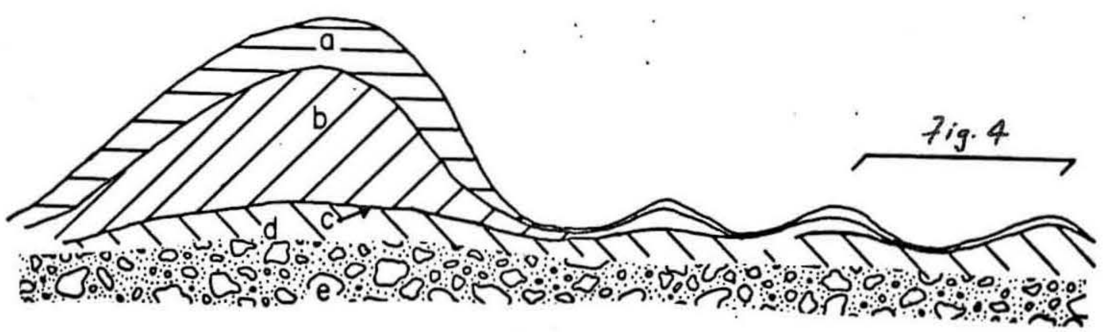


Figure 3: Schematic cross-section of conical mound and adjacent tundra, physiographic segment II. a) little decomposed, loose, coarse fibrous organic matter (mostly moss); b) red to dusty red, slightly decomposed, coarse fibrous organic matter (mostly moss); decomposition increases with depth; c) black, completely decomposed organic matter; d) sapric peat; e) gravelly loam

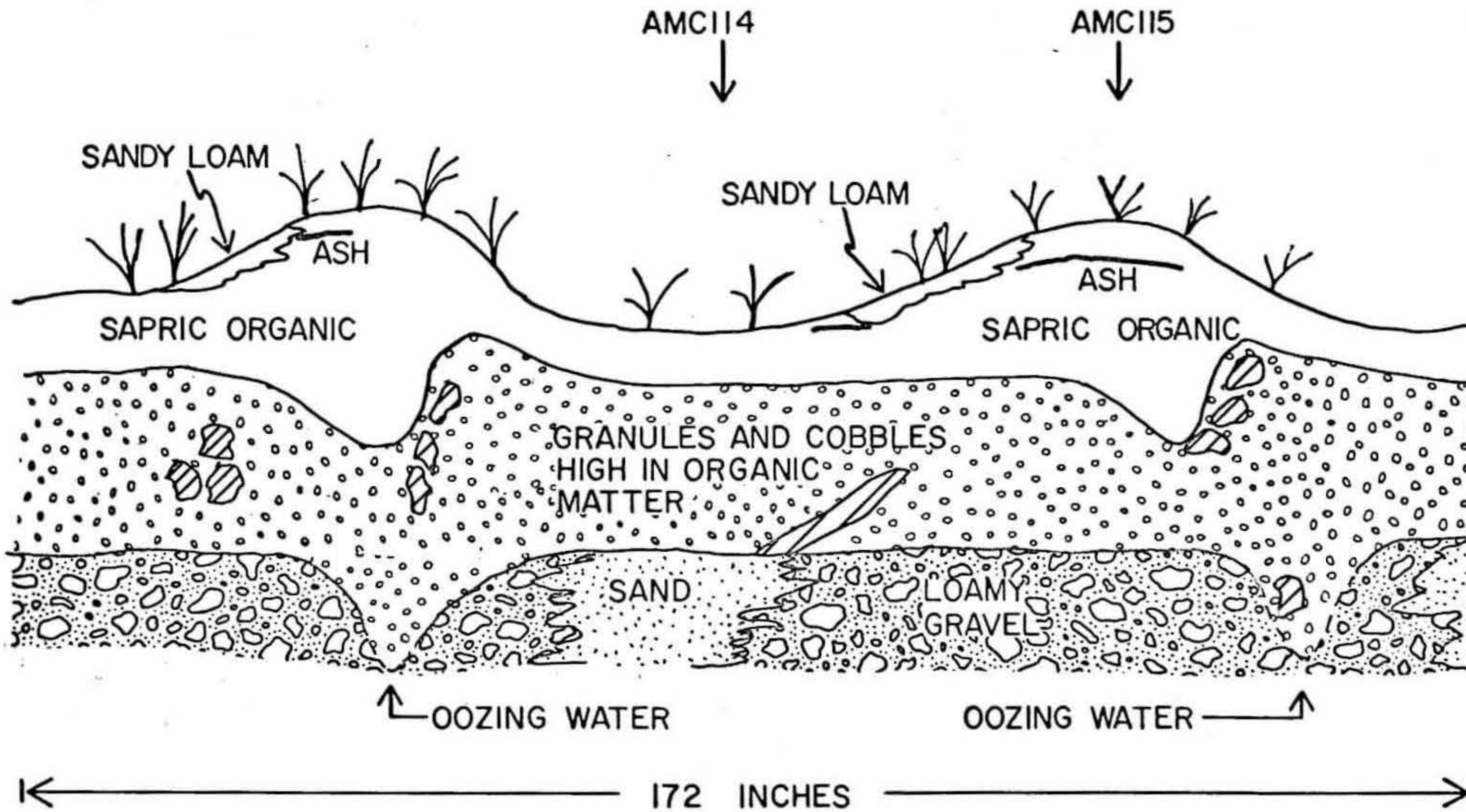


Figure 4: Schematic cross-section of tussock tundra, physiographic segment I; see Appendix A for profile descriptions, Appendix B for chemical analysis. Both profiles are of soil group bh.

The ribbed pattern so characteristic of solifluction sheets on other portions of the Island, see page 54, and designated Crowberry stripe (Amundsen, C. and Clebisch C.E.E. 1968) see page 52 under description of soil group bh, is thought, on the basis of excavation to reflect a topographic reversal of a periglacial form, i.e., a stone stripe.

The third physiographic segment of the Island extends from Makarius Bay westward to the vicinity of Banjo Point. The central upland flat is lower in elevation than the previous segment from which it is separated by the Constantine Harbor Graben,(Powers _et al._, 1960). Lakes are more numerous and of larger size than on the eastern segment. They occupy depressions in the upland, some of which are surrounded by low vegetation-covered hills. Some lakes drain into one another but others appear to have no outlet. North and south of the upland the topography becomes more uneven and the subsurface connection between ponds is more apparent.

Stream valleys are generally broader and head further into the upland, some clearly draining the upland lakes. Most streams enter the sea directly through valleys which are narrow, flat-floored, and 25 to 75 feet deep near their heads. Many of the valleys show considerable evidence of valley wall slumping in their more confined upper courses. As they approach the coast they broaden out. The streams in both segments of the valleys occupy narrow, slightly meandering, incised courses, and the lower courses of most appear graded to present sea-level or storm beaches several feet above sea level. The stream channels are floored with sands and gravels and/or organic-rich silts and clays. Many stream courses, particularly in the area between Cyril Point and Banjo Point, show a clear lineation which appears to be structurally controlled, as Powers et al. (1960) suggest. Several large, steep-sided valleys in the area of Cyril Cove seem clearly related to normal and graben-type faulting.

Those valleys reaching the south coast have broader lower courses than those to the north (which are in many respects similar to those reaching the north coast or raised platform on the east segment). Clearly these broad valleys were not cut by, and do not appear to be presently cut by, their present streams. Perhaps as Powers et al. (1960) suggest, they owe their broad profile to glacial action. It is more reasonable to view them as being cut by more active streams in the past which were graded to a lower base-level than exists today. Since that time they have been aggraded. A large alluvial fan occurs near the mouth of a valley (Qal on geologic map, just to the northwest of Makarius Bay). The fan is probably related to aggradation of the valley, perhaps during the last periglacial period to affect the Island. This stream is now relatively inactive.

Most stream valleys in this segment have one and more commonly two well-defined knickpoints in the form of low falls or riffels over bedrock. Indeed the cross-section form of many valleys changes abruptly as the knickpoint is crossed. The presence of knickpoints indicates recent or relatively recent downward readjustments of base level (in most cases sea-level).

Present marine erosion has ceased to be a factor in sea cliff erosion along much of the south coast (except possibly during periods of intense storms), with sea stacks and headlands the exception, An extensive strand flat is developed on the south coast. The same does not appear to be true for the north coast, where the sea cliffs are actively being eroded by wave action, wind and mass-wasting.

As one moves westward across Segment III, elevations increase, drainage becomes more clearly defined, and the number and size of lakes decrease sharply.

In the fourth physiographic segment elevations increase gradually westward from Banjo Point to the vicinity of Chitka Cove. The amount of undissected, plained upland surface diminishes until near Chitka Cove only isolated remnants of this surface remain. Wind erosion has produced a lag gravel over much of the upland. Near the western limits of this segment patterned ground features, especially contour oriented turf-banked terraces become common.

Most stream valleys, particularly those on the south side have at least one knickpoint. Many of the streams head in shallow, amphitheater-like basins, a characteristic not typical of the more eastern segments. This may in part reflect a change in bedrock lithology or structure but more likely reflects a more advanced stage of geomorphic cycle.

Numerous linear elements can be seen on the sides of seaward trending interfluve spurs. These are thought to represent short term strand-line positions. The crests of some of the interfluve spurs also appear to have been bevelled. Two and occasionally three clearly defined, although interrupted, marine platforms exist in this area.

The remainder of the Island is underlain by the Chitka Point Formation. Physiographically it can be divided into an eastern mountainous segment V, extending between Chitka Point and Windy Island. The western segment VI, between Windy Island and Bird Cape, is a plateau.

Physiographic Segment V, the eastern or mountainous section, has summit elevations generally above 1000 feet, and occasionally they reach 1100 feet. Although local or relative relief is considerable, 650 feet, the general accordance of summit levels leaves little question that they are remnants of a once plained surface which has been elevated by faulting (Powers, et al, 1960) and subsequently dissected. It is morphologically the oldest part of the Island.

Perhaps the most prominent geomorphic elements of this segment of the Island are the four major north facing cirque-like valleys. The valleys head in steep, scree covered walls and are separated from one another by steep, sharp crested arêtes. A narrow arête ridge which runs roughly down the center of the Island divides these valleys from broader, much less distinct amphitheater valleys opening to the Pacific.

The cirque like valleys facing the Bering Sea contain numerous small and medium sized lakes concentrated on the less dissected area near the coast. The smooth, bowl form of a cirque valley is lacking, instead the valleys descend from the base of the head wall in two to three distinct levels. These levels usually correspond to knickpoints and are considered to represent marine erosion levels. Bedrock forms, especially in the lower-seaward parts of the valley are sculptured (steep face facing inland) and strongly linear in plan due to geologic factors. The linearity splays toward the head wall.

Sculptured bedrock prominences on the upper terrace levels have their steep face seaward. No unquestionable glacial deposits were found in the valleys. Powers, et al.,(1960) noted numerous striations. The writer, however, was unable to find any unquestioned striations. The relative softness of the volcanic rocks and the intense weathering, both physical and chemical contribute to accentuating lineations, i.e., micro-fractures, etc., but have surely destroyed any glacial markings if they were ever present.

The cirque like valleys of Amchitka Island were probably formed by marine erosion along zones of structural weakness in the volcanic rocks. Progressive elevation of the Island has resulted in two to three periods of valley widening by marine erosion. Large snowbank accumulations do not occur near the headwalls. The questionable small protolus rampart near the base of one valley headwall suggests that in the past, under a cooler climate, small semipermanent snowbanks may have occurred.

Although the valley walls are steep, usually more than 30°, they are quite stable. The coarse, blocky scree often has a well developed organic soil cover. Numerous excavations in the valley walls indicate two or more episodes of mass movement and scree accumulation separated by periods of soil formation.

Active forms of mass-wasting do occur in this segment and are often closely associated with extensive zones of fault gauge. They occur with upland soils, see Plate IV and page 83. The forms include turf-banked terraces and stone stripes. In some areas the terraces are breached and mineral soil and rocks from the tread of one terrace spill over to the next. By this process considerable amounts of soil and rocks are moved downslope.

Disintegrating bedrock highs (Tors*) and solifluction lobes are common in the section, see page 83. The tors, with their disintegration products forming an apron to the south, suggest ice movement from north to south.

Multiple solifluction* lobes are moving in wave fashion down the hill slopes, leaving behind exposed bedrock cores or relatively flat lag-gravel surfaces. The amount of organic material involved in the solifluction lobes and that which they bury suggest that this is a relatively recent phenomenon. Their movement exposes mineral soil which was once covered by a thick organic blanket similar to that of the two eastern segments. This active mass-wasting may have come about through recent uplift in this already climatically more alpine section of the Island. There is evidence, page 76, of an earlier period of solifluction.

The natural slope instability of the steep bluffs facing the north coast and above the elevated marine platform segments is amply

---

*See glossary, Appendix C

demonstrated by the very large _en echelon_ slump blocks in the vicinity of Chitka Cove. These features are clearly of the slump type with deep, curved slip surfaces. They appear to be old and presently stabilized. Less spectacular, but no less important in the total picture of mass-wasting, are the smaller debris slides currently active along the sea cliffs and inland bluffs of this section.

Most active debris slides involve only a thickness of several feet of material, either organic mat with minor amounts of mineral material or mineral material alone. The plain of weakness appears to be the contact between the organic mat and the underlying sandy soil. Re-establishment of vegetation on slopes as steep as 30° does occur. The actively eroding sea cliffs probably do not re-establish a vegetation cover. It is clear that some of the relatively stabilized slopes are being over run by material moving down from the barren, terraced uplands.

The south facing amphitheater-like valleys appear much less cirque-like than the north facing valleys just discussed. They are broader and topographically more complex. Three major step-like levels (marine beaches) occur in each valley system and are accompanied by knickpoints. The mouths of present valleys are graded to sea-level (unlike the north facing valleys, which usually cross a knickpoint before reaching the sea).

The general north-trending linearity is complicated by a series of west-trending fault traces. Individual topographic elements are thus somewhat rectangular. The degree of hill-slope stability is high although solifluction (creep) does occur. There is little active sea cliff erosion and sea stacks are very few.

Physiographic segment VI is a plateau area between the position of Windy Island and Bird Cape. Morphologic elements are directed at an obtuse angle to those of the previous section. It might be surmised the two sections are separated by a fault or fault zone.

Streams head in very broad amphitheater basins. The undissected upland is areally much more extensive than is the mountain section and ranges in elevation between 700 and 850 feet (Powers _et al._, 1960). It is for the most part a lag-gravel surface with only a few, small and shallow ponds. Lag fragments are mostly angular, but as noted by Powers, _et al_, (1960) there is a component of rounded fragments, see Figure 5. The occurrence of such pebbles in areas other than Square Butte suggests a marine origin.

Frost action is active; large, partially stabilized and eroded sand dunes dot the surface. Smaller, contour oriented dunes are also common, their eroded sides facing south-east.

At the very western end of the Island elevations drop abruptly some 300 feet to a marine platform with elevations 60 to 100 feet above present sea level. Remnants of a similar raised surface can be found in the lower reaches of the amphitheater-like valleys. A large proportion of the streams in this segment are graded to current sea level, below the first prominent knickpoint.

No unquestioned glacial striations were found in the region, although (Powers, _et al._, 1960) indicates their presence. Several

Figure 5: Well developed, sorted circles developed on the bottom of a drained upland pond in physiographic segment VI. Shovel is 40" long. Note proportion of large rounded cobbles, perhaps of marine origin (?)

rounded erratic blocks, Figure 6, were found. The block pictured was resting on the stoss side of a hill near the crest. Several other blocks were found on a vegetation covered lee slope. The blocks are not erratic in the sense that they are of a bedrock type foreign to the area. Rather they are erratic in form and position. They appear to have been derived from bedrock outcrops across the valley. Ice would seem the logical mechanism for movement. However, this was ice either moving across the Island in a general southerly direction, from the Bering Sea, or more likely ice from a small Pleistocene cap located on the upland plateau. The glacial history of Amchitka Island and the Western Aleutian Islands in general require considerable study beyond the observations made to date.

Except for a relatively recent landslide, see page 80, on a steep bluff above the raised block southeast of Aleut Point the area appears stable.

Ponds and Lakes

The ponds and lakes which occur in such abundance over the eastern half of Amchitka Island, especially in segments I, II, and III, display different morphologies and undoubtedly represent several different modes of formation. A generalized and very much oversimplified grouping of pond types is presented, (Everett, 1967).

Group 1 -- Ponds of this group occur on upland areas. They are small and shallow (about 1 foot deep). Shorelines consist of a

Figure 6: Erratic block, physiographic segment VI. Shovel is 40" long.

turf roll which may be slightly undercut by wave action. Many of these ponds have no apparent inlet or outlet. Most appear to serve as catchment areas for local drainage and rainfall. The pond bottoms are covered with silty-organic mud. Ponds of this character are most common in segments I and II.

Group 2 -- Ponds of this group also occur on the uplands and in areas of gently rolling topography. Depths range from 1 to 3 feet and the turf shorelines show undercutting. Generally, ponds of this group are somewhat larger than those of group 1. Many show no apparent inlet or outlet, others do. However, most do not appear to occur in any form of an integrated drainage system. Organic silts and muds cover the bottoms to at least 6 inches and beneath this there may be a layer of gravel and cobbles.

Group 3 -- These ponds occur in areas of topographic dissection or occasionally on upland areas. Almost all show either surface or subsurface inlets and outlets and are clearly a part of an integrated drainage. Depths range from 1 to 4 feet or more and most are of sufficient size to permit small waves to undercut their turf shores. Commonly this group of ponds will show one or several elevated shore lines. In many cases a rocky apron extends for some distance from shore. In the deeper central areas of the ponds the rocky bottom is covered with 6 or more inches of alternating fine organic-rich silt and sands. When mechanically disturbed these sediments are thrown into suspension. Pond clearing after disturbance is rapid, requiring only a few minutes.

It is difficult if not impossible in most cases to determine whether or not a particular pond is the result of a bedrock depression. Many undoubtedly are, particularly in the western segments of the Island. The upland ponds in segments No. I and No. II are suggestive of thermokarst* development and may owe their time of origin to a period when the Island was underlain by permafrost*, see section on soil genesis.

Ponds of group 3 drain one to another via a largely subsurface route. Many of the shallow swales between ponds are actually false valleys. The stream flows over compacted peat, or in some cases mineral soil several feet below the surface. This can be seen in many places where false valley floors have collapsed, leaving circular pits and exposing the stream below, see Figure 2. Small surficial streams frequently plunge beneath the surface through small conical pits to emerge in the next lower pond. This type of stream behavior is a close parallel to the karst drainage of limestone areas. Underground flow may be closely related to the fracture system developed in sapric peat.

The drainage and partial drainage of several ponds is clearly attributable to the collapse of small areas of their bottoms into an underground conduit which had otherwise no visible surface expression. In other areas where caving and sink hole development was observed nearly circular conduits up to 22 inches in diameter ran beneath the peat, Figure 7. Surface collapse of the peat in the

* See glossary, Appendix C

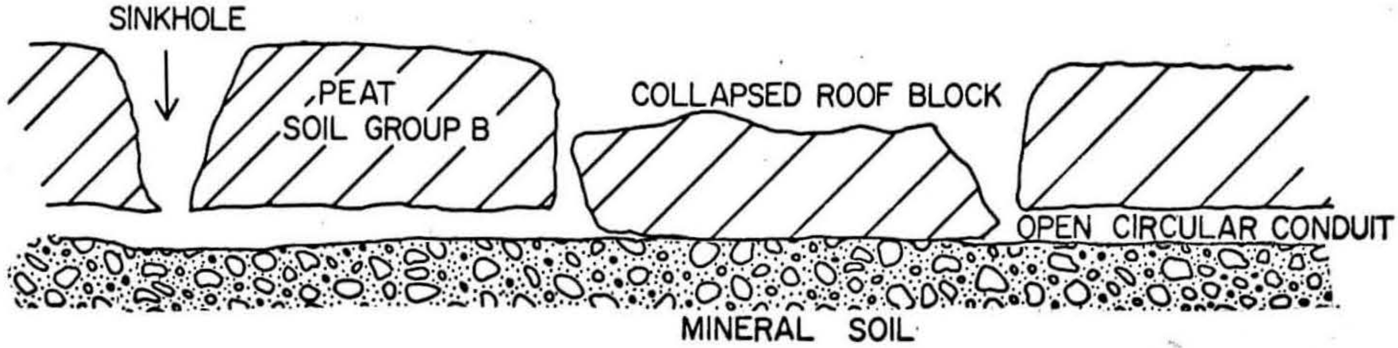


Figure 7: Schematic longitudinal cross-section of Karst valley showing collapsed roof segment and open water conduit and sink hole. Compare to Figure 2.

form of sink holes and linear depressions is common on the Island, but in segments IV, V and VI it seems to have progressed to the point where most streams are now exposed over much of their length. This is perhaps attributable to a fairly recent change in base-level due to uplift.

The levels of many ponds on all parts of the Island were down from a few inches to several feet from previous recent positions, some dried completely. This may in some small way reflect a dryer than normal summer (1968), but more likely records better drainage either surface or subsurface. No one physiographic segment seems to be favored in this respect.

Soil profiles taken from the most recently abandoned level (shore) of group 3 ponds indicate that the level had been abandoned prior to the last major ash fall. If Schacklett's (Schacklett, 1968) radio carbon date is accepted for this ash, then many of the ponds have been in existence for at least 700 years. The progressive lowering of the water level may reflect changes in regional base level induced by uplift.

SOILS

The soils of the Aleutian Islands have received only slight attention. The brief account of some of the soils of Adak Island (Ulrich, 1951) and a detailed account of the soils of Kodiak Island (Rieger *et al*, 1960) constitute the bulk of soils information on the Aleutian chain. The soils of Kodiak Island are morphologically quite different from those of either Adak or Amchitka Islands. The early soil survey of Alaska (Kellogg, C.E., and Nygard, I.J., 1951) refers to the soils of Amchitka as Tundra without permafrost. Later reports (Rieger *et al.*, 1960) refer to some of the soils of Kodiak as "ando-like", implying a morphological if not genetic similarity to the ando soils of Japan. Other workers (cited in Rieger *et al.*, 1960) have referred to the soils of the chain, principally the outer islands, as Tundra without permafrost. None of these descriptions is adequate and none applies to Amchitka or probably the adjacent islands. Amchitka soils have at least a partial counterpart in north Scotland and in some of the soils on northern Iceland (Johannesson, B., 1960).

The descriptions and discussion that follow attempt to portray the morphological and chemical range of the Amchitka soils, which was to serve as a basis on which to judge their reaction to test activities and on which to define the natural slope stability of the Island. In addition, this work will provide detailed information on a group of soils unique to North America.

Soil Drainage Categories

The soil characterization for Amchitka Island which follows is based in part on the following drainage classes (Soil Survey Staff, 1960).

Class 0. Very poorly drained: includes soil groups a_1 and a_2. Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Surface water may be standing or slowly circulating.

Class 1. Poorly drained: soil is wet a large part of the time. Class includes soil group b.

Class 2. Imperfectly to somewhat poorly drained: water is removed from the soil at rates slow enough to keep it wet for significant periods of time. May contain a slowly permeable layer. Class includes soil group bh.

Class 4. Well drained: water is removed from the soil readily but not rapidly. Class includes soil groups c and e.

Organic soils

Soil group a_1 -- Soils of this group are very restricted in extent and represent the poorest drainage (class 0) on the Island. They occur occasionally in old lake beds and on broad valley floor areas where ponding is frequent. In most instances the mid-summer water table stands within 12 to 20 inches of the surface. During spring and periods of high water it may rise to the surface. When at the surface the water is either standing or very slowly circulating. Such areas commonly support a dense, rather pure stand of Carex sp. growing in moss. Beneath the layer of living material are one or more thin layers or horizons of moderately decomposed very dark brown to black organic matter, designated either as Hemic* or Sapric*. However, the bulk of the profile to 40 or more inches is composed of a succession of layers or horizons of little decomposed dark reddish brown to very dark reddish brown 7.5 yr 2/2 - 3/2** coarse to medium fibrous (Fibric*) organic material.

Because of the coarse fibrous character of the peat and its poorly drained topographic position field moisture contents are high, 1256% average. Bulk density values on the other hand are low, averaging 0.09.

Disseminated mineral material is rarely found in the organic part of profiles of soil group a_1 . Discrete layers of ash or sand are very rare.

Where the organic-mineral soil contact has been observed, the mineral soil is a blue clay or occasionally a blue, medium to coarse sand. The color is indicative of reduced iron.

The uncrushed fiber content of the Fibric horizons (a_1 soil) range between 50 and 90+%, commonly it exceeds 80%. The crushed

---

* See glossary, Appendix C

** See glossary, Appendix C

fiber content ranges between 10 and 60%, see general definition for Fibric horizon, Appendix C. The micro morphology of typical Fibric material is shown in Figure 8. As a rule the little decomposed fibers show a strong preferred orientation parallel to the surface of deposition. There is a large amount of void space which is directly correlative to the low average bulk density and high water-holding capacity. Amorphous aggregates are much reduced in number compared to either Hemic or Sapric sections, Figures , 12, and 14. Thin-section analysis revealed a negligible amount of mineral matter in the Fibric horizons.

A typical profile for soil group a_1 appears in the Appendix, also see Figure 9. Standard soil chemical analyses are also included. These analyses were run on samples at field moisture which introduces a considerable error. This has been considered acceptable as it does not influence trends. It probably reflects a range in actual field conditions.

The considerable amounts of exchangeable cations in all horizons and especially in the middle horizons reflect the low decomposition stage of the organic matter and lack of leaching. A probable mineral layer appears near 24 inches and is reflected by a sharp decrease in all values, especially in percent of organic carbon. This thin textural break was also identified in the field description as a shift from Fibric to Hemic organic matter. The horizon may correspond to the upper mineral layers (ash) of other

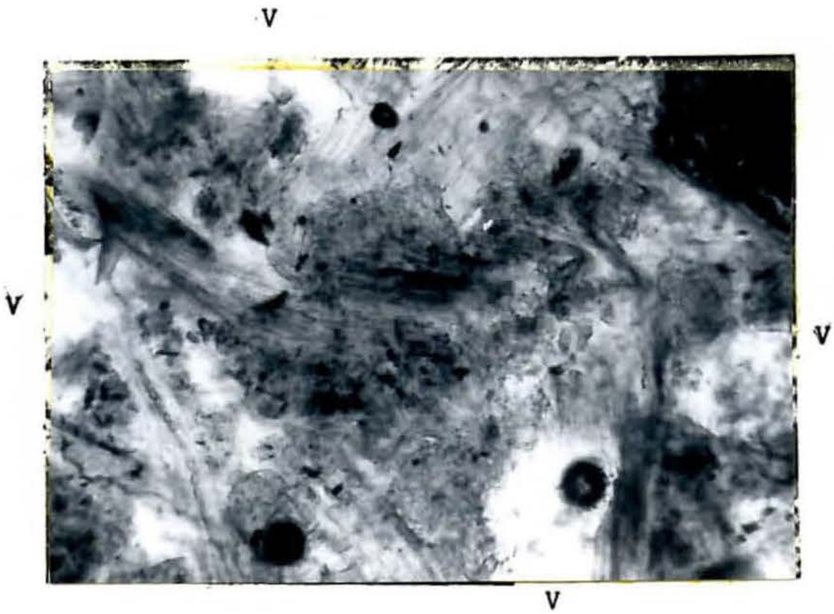


Figure 8: Photomicrograph of fibric peat. Note coarse texture and abundance of fibers. Amorphous aggregates absent. V (Voids)

Figure 9: Typical profile of soil group a_1 , photographed against vegetation of area. Physiographic segment III. Note coarse fibrous character of Fibric peat.

soil groups. Its depth here reflects a higher rate of organic accumulation and decreased oxidation. It does not seem to be universally present in this soil group.

The presence of a Sapric and Hemic horizon in the upper 5 inches of the profile reflect an increase in degree of organic decomposition which may be related to relatively recent natural or artificial drainage or to masceration as a result of World War II vehicular travel.

Soil group a_2 -- This areally extensive, poorly drained group of soils occupies low relative landscape positions, see Figure 10, for position in idealized toposequence. It is physically and morphologically closely associated with soil group a_1 and b and may in certain areas be associated with soil group bh, page 15 in segment II. In general they occur on upland areas, (plateaus of low elevation), near coastal lowlands, see map plates I and II and in shallow swales and foreslopes.

These soils are poorly drained (class 0), although better drained than those in group a_1 . Slope angles range generally between 3 - 10°. Vegetation cover usually consists of Carex sp., Cladonia pacifica and other Cladonia sp., other lichens, mosses and some Empetrum nigrum. Characteristic of these soils is a gelatinous layer just below the vegetation mat. The distribution of this soil group closely coincides with the "break-away" community as defined

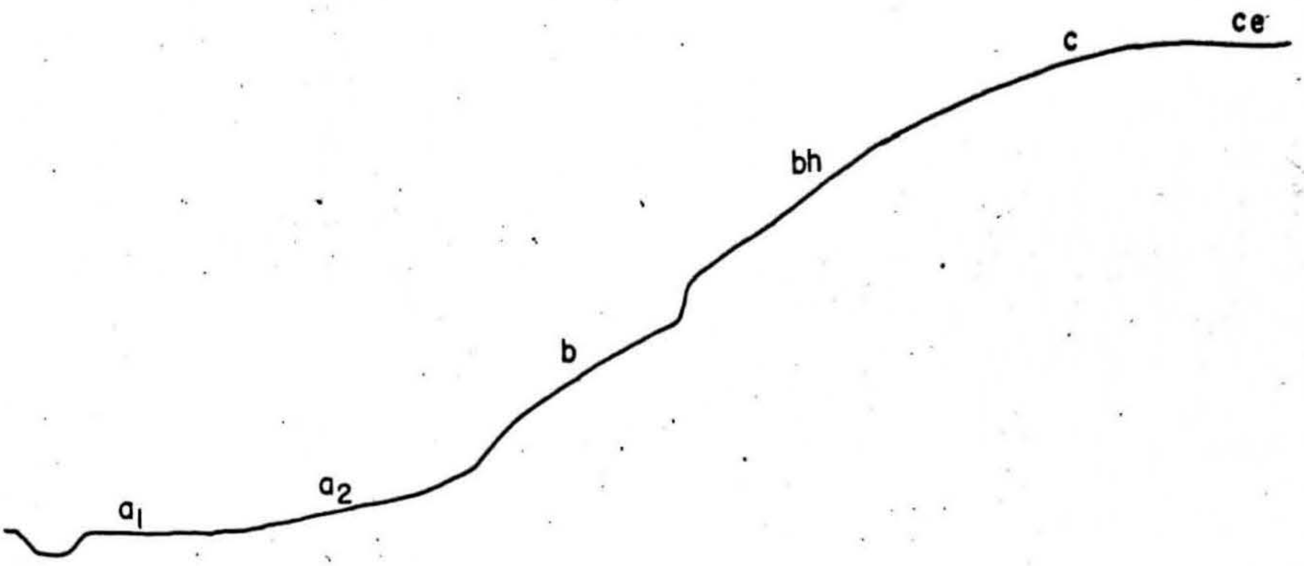


Figure 10: Idealized toposequence showing relative position of major soil groups of Amchitka Island.

by (Amundsen, C. and Clebisch, E.E.C., 1969).

In general the profile is comprised of a succession of organic horizons, both Fibric and Hemic, Figure 11. Horizons of Hemic texture tend to dominate.

The upper horizons, both Hemic and Fibric, tend to be somewhat darker in color than those lower in the profile which indicates better aeration and oxidation. Uncrushed fiber content in the Hemic horizon ranges between 30 and 60% and crushed fiber contents 15 to 30%. These values are well within the defined limits. Moisture and bulk density values range moderately between Hemic and Fibric horizons. Considering the profiles as wholes the values are significantly lower than for soil of group a_1, falling generally within the defined limits for Hemic textured organic matter; average field moisture and dry bulk density values are 620% and 0.16 respectively.

Two and occasionally 3 mineral layers are developed in profiles of this soil group. The upper one is commonly found between 5 and 7 inches. The lower ones at about 17 and 19 inches, respectively. Where they are encountered they form a physical as well as a textural break. Thin section and grain mount analyses have definitely established these mineral layers as volcanic ash, see page 65 for discussion of composition on significance of mineral horizons.

Soils of group a_2 range rather widely in depth but usually exceed 40 inches. Where the mineral organic contact has been observed it consists of a concentration of rounded or subrounded cobbles and

Figure 11: Typical profile of soil group a_2 photographed against vegetation of area. Physiographic segment I.

boulders and mineral matrix. These materials have dark colors which probably represent a concentration of organo-ferrious material moved down higher in the profile.

The general micromorphological characteristics outlined on page for Fibric horizons in a_1 soils are generally applicable for horizons of Fibric texture in group a_2 soils. Examination of thin sections of Hemic material, Figure 12, indicates large voids, some up to 1/2 centimeter in length ; also vacated root channels are common. Fillimentous and cellular plant fragments are scattered throughout and most sections show a general tendency to platyness although much less so than the Fibric sections. Perhaps most characteristic of the Hemic material is the large increase in amount of amorphous material. Much of this material appears as angular and subangular blocky units up to 800 μ or more. Most units are composed of rounded and sub units up to 80 μ which contain lignitic organic fragments, occasional diatoms and rarely mineral grains (very fine silt size). Free mineral grains of larger size are rare, most are weathered Feldspar. Fungal hyphae and fruiting heads are common.

The general decrease in pore space, fungal material, darker coloration, and increase in bulk density all point to a greater degree of decomposition for the Hemic horizons.

Two representative profiles of a_2 soils are presented in the Appendix, as well as a representative chemical analysis of one of them. The presence of two mineral horizons is immediately apparent

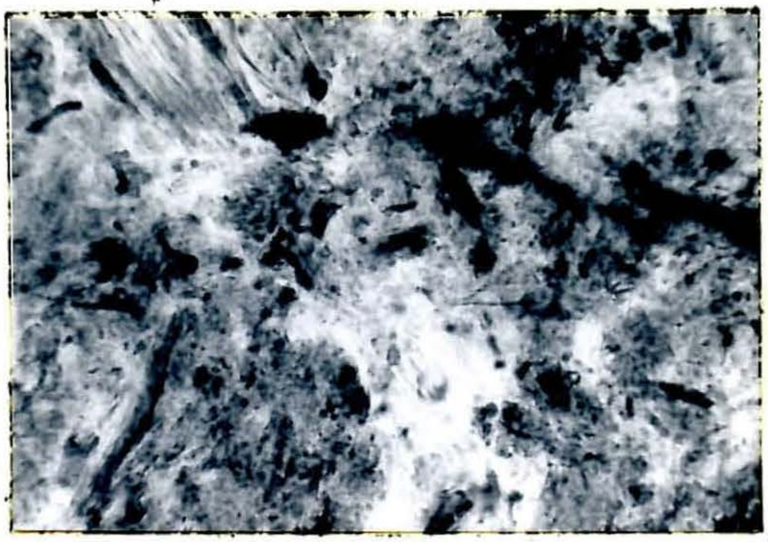


Figure 12: Photomicrograph of hemic peat. Note occasional plant fibers (F) and amorphous aggregates (A).

from the analysis in the form of increased pH values and marked decreases in all other values. When the analyses of this soil are compared with that representative of soil group a_1 several things become apparent: 1) Weight loss on ignition and organic carbon values are approximately the same in both. This indicates the actual amount of organic matter is pretty much the same; 2) The fact that pH and values for the exchangeable cations all decrease indicates the more advanced stage of oxidation of a_2 soils. It is necessary to mention here that the analysis of the a_2 profile was on air dryed material. This may account for some of the decrease in cation concentrations. Organic soils in general tend to be hydrophobic, that is they do not rewet completely after drying, thus some of the otherwise exchangeable cations may have been rendered inextractable.

It should be noted also that no Sapric horizons appear on the surface of the selected a_2 profiles. Neither of these had been subjected to vehicular or foot traffic in the past and are thus unaltered.

<u>Profile variations</u>

No geographical variations were noted in group a_1 soils. In soils of group a_2 two such variants are noted: 1) Typically, a_2 soils have 1 to 3 inches of living vegetation over the soil surface. However, in certain areas near the coasts and more commonly on hillslopes soils having a typical a_2 profile have developed over them as much as 12 inches of spongy living moss, ferns and <u>Carex sp.</u> The thickness as well as the composition of the vegetation mat is unique. These profiles commonly have a higher field moisture status than is typical of a_2 soils. Possibly they represent the position of peached water tables. Because of these differences they have been separated out on the soil map of the Island and designated a_2t. These soils are most frequently encountered on raised beaches in Island segments I through III. The second variant occurs most commonly in sections III through VI. Again the profile is that of an a_2 soil, however the amount of mineral matter (sand grains) increases substantially. In these physiographic areas a_2 soils are frequently closely associated with lag gravel surfaces. The sand in their profiles is wind blown from these surfaces. Toward the coast in these sections (away from extensive lag surfaces) the normal profile is developed. Because of the great variability in distribution of this subtype and because the included sands probably have little effect on the soil either from the standpoint of its chemistry or trafficability it has not been given a separate map designation.

Soil group b -- This group of poorly drained (class 1) soils is widely distributed over the Island, increasing in abundance from east to west. These soils occur on slopes between 3 and 33°, and in a topographic position intermediate between group a_2 and the moderately well drained group bh soils, see idealized toposequence, Figure 10. Where profiles occupy positions transitional to bh soils the horizon succession is dominated by Sapric* texture and extends to depths of about 20 inches. When transitional to a_2 the soil depth may reach 70 inches and is dominated by Hemic horizons. The midslope position b soils, described in the Appendix, are developed under crowberry-grass-sedge community (Amundson, C., and Clebisch, E.E.C., 1969).

Hemic horizons ordinarily occur near the surface, and rarely at depth. They are more reddish 5 yr 2/2 than in a_2 soils. The remainder of the profile is composed of a succession of Sapric horizons. Both uncrushed and crushed fiber contents are low, usually below 10%. Sapric material unlike either Hemic or Fibric material lacks recognizable organic fibers, is moderately dense, average bulk density for soil group b is 0.26.

The Sapric organic material of this soil group usually offers some resistance to crushing. It breaks into angular blocky , or weakly platy structural units. Average field moisture for group b soils is 354%

Three thin mineral layers or horizons are well developed in soils of this group. The upper mineral layer usually occurs between 5 and 7", the lower two layers between 9 and 10 and 10 and 11 inches. The upper mineral layer generally constitutes a pronounced physical break.

In addition to the mineral horizons, discontinuous zones of Plinthite* are a common occurrence, especially in b group soils

---

* See glossary, Appendix C

Figure 13: Natural fracture pattern developed in bh soil.

transitional to those of a_2. Plinthite is formed by iron hydroxide and/or iron hydroxide-organic materials being precipitated at a textural discontinuity or at the water table and subsequently oxidized. In b group soils it represents the position of a past high water table. When subjected to oxidation the iron compounds assume a reddish color. Plinthite may become hard and impermeable or remain soft. In many b group soils abandoned root channels are coated with iron oxides and the Sapric organic material may be mottled with rust colored spots . All of this indicates a fluctuating water table, again particularly in the b soils transitional topographically to a_2.

Occasionally a columnar fracture pattern develops in b group soils, especially those transitional to bh, Figure 13. These fractures are coated with iron hydroxide and are obviously pathways for water movement.

The mineral soil-organic contact is generally sharp. The mineral soil can usually be separated on the basis of texture and color into 2 or more horizons. They are usually reddish or dark reddish brown, (oxidized) sandy or gravelly loams. Most contain some organic matter, see chemical analysis. The upper mineral horizon is commonly induated with iron and silica indicating deposition from downward percolating waters. The resultant paralithic contact with the organic succession is thus a zone of weakness and slides are common along it.

Thin section examination of Sapric material, Figure 14,

Figure 14: Photomicrograph of sapric peat. Note dense texture and fungal hyphae.

characteristic of group b soils indicates a high degree of compaction of material and almost no plant cell structure is visible. The overall state of decomposition is high. Small voids and occasional vacated rootlet channels are common. Nearly the entirety of the thin sections are occupied by amorphous organic material. Fungal hyphae and fruiting bodies are abundant. Diatoms and caprolites are infrequent. The amount of fine grained mineral matter increases significantly in Sapric material. It consists of quartz, highly corroded Feldspar laths and occasional highly corroded pyroxenes.

Representative profiles and general chemical and physical aspects of a modal type b soil and a variant (sandy phase) are presented in the Appendix. The fundamental differences between these two soils, i.e. increase in mineral material, are immediately apparent in the form of an increase in pH and decrease in organic carbon values for the sandy phase b soil.

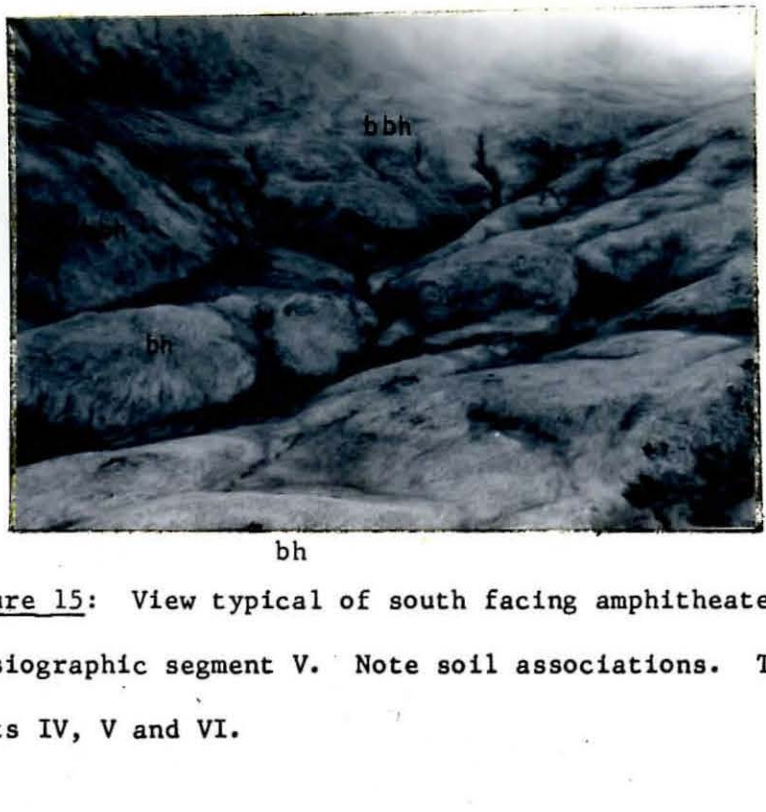
Marked differences also occur between the modal type b soil and soils of other groups. The dominance of Sapric organic material reflects the much higher decomposition state of the organic matter, i.e., state of oxidation. The amount of extractable Fe_2O_3 in the underlying mineral soil reflects not only greater oxidation but also a zone of concentration of iron-organic compounds. This is greatest in the sandy phase b soil and may reflect the solubalization of iron compounds released from the mineral constituent of the organic matter, i.e., the mineral matter added from the adjacent deflation pavements.

PH values are intermediate for the Island soil groups in general. The values for the sandy phase b soil are somewhat higher than the modal soil, due again to the mineral addition.

Profile variations

The variation the profiles of group b soils has already been mentioned. The modal profile of group b soils is applicable to a midslope position in Island segments I through III. Beginning in segment IV and continuing westward the sandy phase of the soil dominates. This is particularly true at higher elevations where it is associated with lag surfaces and soil groups c and ce. In such areas the ideal toposequence does not apply and sandy phase group b soils may occur in a$_2$ topographic positions, Figure 15. Toward the coast (lower elevations) away from the lag surfaces, the normal toposequence occurs and the modal b soils replace the sandy phase variety.

Soil group bh -- This group contains imperfect to somewhat poorly drained (class 2) soils. These soils are best developed on slopes between 2 and 15° and occupy a position topographically above soils of group b, see toposequence Figure 10. Their vegetation cover corresponds closely with the crowberry-sedge-grass community described by (Amundsen, C., and Clebisch, E.E.C., 1969). A characteristic feature of these soils is the development of a surface pattern.



bh

Figure 15: View typical of south facing amphitheater-valleys in physiographic segment V. Note soil associations. Typical of segments IV, V and VI.

Where this occurs in the form of stripes, the vegetation designation is crowberry-stripe community. In other areas, especially those of low relief (see soil map, Section II) a low hummock topography occurs. Frequently soils of group bh can be separated from those of group b by noting the position of a conspicuous roll or break in slope. The soils of the roll and/or above the break in slope are bh, see Figure 16.

Numerous profiles of bh soils from all sections of the Island show them to be relatively shallow, 18 to 25 inches and below the vegetation base composed entirely of Sapric organic material, figure 17.

The Sapric organic material although falling well within the limits for such material, Appendix C, page 148, is texturally quite different from that which characterized b group soils. There are no identifiable plant remains although living roots and rootlets may be observed, especially abundant in the thin granular surface horizon. It is somewhat more brown, 10 yr 5/6, very dense, bulk density 0.36. Most sapric horizons of this soil group offer weak to moderate resistance to crushing and may best be described as "brittle". Upon crushing the material breaks to moderate to strongly developed coarse angular and subangular blocky units, or a pronounced platy structure. A natural blocky or columnar structure is frequently encountered and nearly always has ferro-organic coatings. Small moderately hard iron or manganese nodules are common in some Sapric

Figure 16: toposequence showing relative position of soil groups a_2, b and bh. Note break in slope between soil group bh and b. Physiographic segment VI.

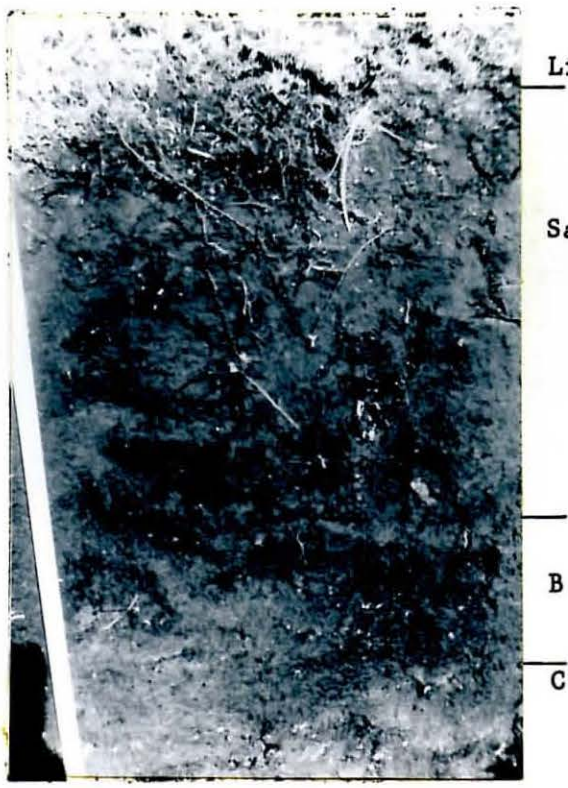


Figure 17: Typical profile of soil group bh. Note depth of rooting and amorphous character of organic material. Physiographic segment III.

horizons.

Careful excavation across the frontal roll, Figure 18, of bh soils or across their striped pattern reveals deep, open 3-4 inch rifts extending down and back into the slope to the mineral soil for as much as 40 inches. The position of these rifts and contorted sand structures suggest active, slow movement.

Soil moisture values are also distinctive for this soil group, the average is 201%. Mineral material ranges from essentially none to a quantity sufficient to designate a sandy phase.

Thin section analysis reveals much of the fine, widely disseminated mineral matter to be quartz and highly weathered pyroxenes and feldspar. Few mineral horizons are encountered, either macro or microscopically in bh soils. The Sapric material in thin section appears much like that already described, page 51 for group b soils. Few aggregates are apparent. Structured units are poorly defined, blocky and range in size up to 50 μ. Numerous small, non-connected voids occur within the amorphous material. Many small rootlet channels are coated with what appears to be hydrous iron oxide and/or ferro-organic compounds. Fungal hyphae and fruiting bodies are abundant. Mottling is not characteristic of bh profiles.

The underlying mineral soil is usually a gravelly, sandy loam containing a high proportion of oxidized iron. A black, greasy feeling Sapric horizon is commonly encountered just above the mineral soil. This horizon probably does not represent a buried soil but

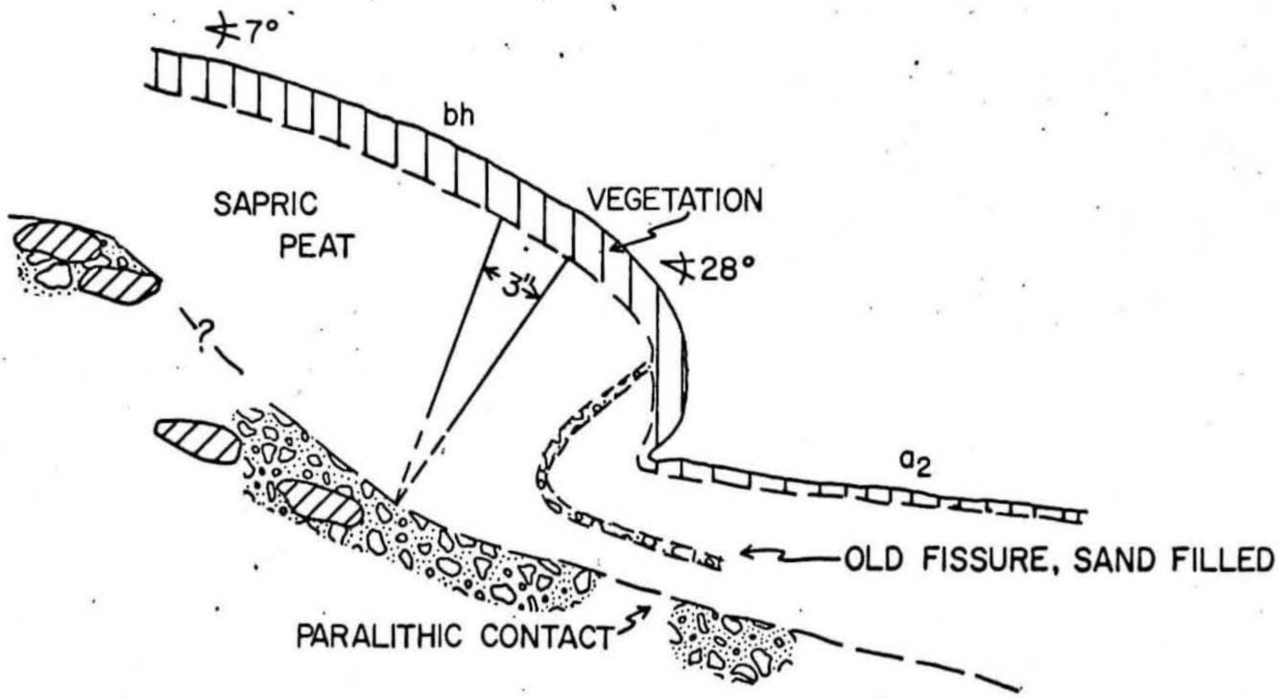


Figure 18: Schematic cross-section showing detail of slope break between bh and b or a_2 soil groups. Open fissure 40" deep is characteristic of these features (leading edge of solifluction sheet). See Figures 16 and 23.

represents a zone of ferro-organic accumulation at a textural discontinuity. The upper mineral soil horizons commonly are strongly indurated. There is little evidence of mixing in these profiles and the mineral subsoils appear to have developed from bedrock <u>in situ</u>.

BH soils have the lowest organic carbon values of any of the organic soils on the Island. This coupled with the reddish brown color of the organic matter attest to its greater oxidation, higher decomposition state; pH values tend to be high, exceeded only by those of the mineral soils. Base cycling, as represented by base saturation is well defined in these soils. They are the only organic soil group where living roots are commonly in contact with mineral soil. All cations are relatively high in the near surface horizons, decrease in the intermediate and lower organic horizons, and then increase again in the mineral soil. Possibly some of the cation increase in the upper horizons is in fact related to wind blown additions.

<u>Profile variations</u>

Just as in b group soils proximity to deflation pavements and c-ce soil groups increases the mineral content of bh soils to the point where in Island segments III, IV, V and VI a sandy phase must be recognized. Because of the map scale this phase has not been separated out. It begins to be a major soil unit from about the position of test site C westward. Near the coastal area in all Island segments the more typical bh soils are developed. Sandy phase bh soils in their most intense development are difficult to separate from soils of group c. The upper horizons rather than being composed of a dense, brittle Sapric material are brown, well aggregated and granular (fluffy).

Mineral Soils

Soil groups c and ce

Soils of this group occupy upland crest positions and solifluction terraces. They are associated with wind erosion and deflation pavements. Ordinarily they are moderately well drained, to well drained (class 4). Soils of group c develop under a complete or nearly complete vegetation cover of crowberry-grass. Slope angles are generally less than 2°. However soils designated as group c may occur on slopes as great as 30° on solifluction terrace risers, Figure 19. Soil group ce is commonly found on terrace treads, see profiles AMC 105 and 128. On terrace risers c group soils are transitional to group bh but are separated mainly on the basis of texture of the surface horizon. Typically this horizon ranges from 6 to 15 inches in thickness and is composed of sandy loam with a large amount of organic matter (Sapric material). The increased drainage results in a high degree of oxidation, both of the organic material and the mineral soil. The organic matter addition to the sandy loam produces a loose, strongly developed granular structure (the consistency of good commercial potting soil). The mineral soil sub horizons range in texture from sandy loams to loamy sand and gravel. This depends upon the bedrock or parent material. The mineral horizons are not indurated. Occasionally a buried soil, Sapric organic matter concentration can be found above relatively unoxidized mineral soil, Figure 19. This occurs in areas of contour terraces and other obvious forms of slope instability.

Because of the exposed and/or unstable positions occupied by c soils their distribution is restricted. More commonly only truncated profiles are encountered. The degree of truncation ranges widely, from simple removal of the organic or O horizon to removal of all horizons, leaving only the unmodified parent material.

In certain areas, principally Island segment VI, where the exposed mineral soil has a high silt and clay content and an incomplete lag gravel cover, a strongly vescicular structure may be developed. Such soils become "quick" and tend to flow under gravity if the correct moisture value is reached.

It is likely that most, if not all the truncated soils were once bh or c group soils and have perhaps comparatively recently undergone wind erosion. There may be brief periods of profile development attendant the incomplete and apparently short lived re-establishment of a vegetation cover.

That the horizons of group ce soils are indeed subsolum horizons is substantiated by thin section study. The feldspars are highly

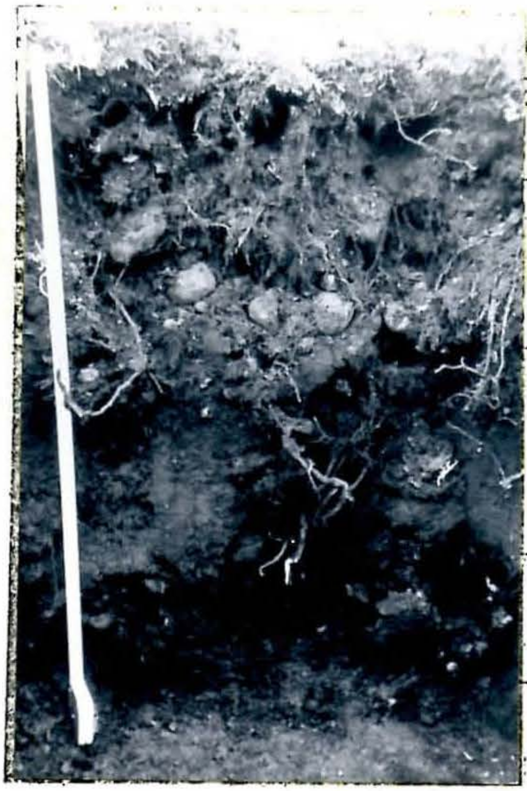


Figure 19: Soil group c. Typical of terrace risers in physiographic segments III through VI.

fractured and show both internal and external alteration. There are numerous subrounded grain aggregates (feldspar splinters in a silty-clay matrix). Many of these aggregates have oriented clay rims and iron-organic stains indicating that material has been moved into these horizons from the now-removed A horizon. In the C horizon of the ce soils as well as the c soil, the degree of feldspar and pyroxene alteration decreases, and grain aggregates, though plentiful, are reduced in the amount of matrix. The amount of void space increases.

The most cursory examination of the chemistry of profiles AMC 60, group c and AMC 54, group ce, is sufficient to show the differences and to illustrate the truncated nature of the profile of soil group ce. The most significant differences are the near lack of organic carbon in group ce and the increase in pH levels. In most cases the exchangeable cations are reduced as well. Both profiles are from Island Segment IV.

Because of the direct influence of parent material on the texture and chemistry of group c and ce soils representative profiles were taken in the more western segments of the Island. AMC 105, see Appendix, is representative of a crest area with a mixture of course lag gravel and pioneer vegetation. It is chemically somewhat more closely related to ce group soils than to group c. The very high exchangeable calcium and magnesium values probably reflect local bedrock composition site. Instability probably does not play an important role here.

A second c group soil,(ce) AMC 128 was described from Island segment VI. It is representative of recent truncation of a group c soil developed on fine textured deposits. The upper 6 inches of this soil probably represent a B2 horizon,i.e. a horizon of illuviation. This is reflected in the increase in organic carbon and present free Fe_2O_3. Increase in exchangeable cations with depth again reflect bedrock composition.

Profile variations

A significant though a really not very extensive soil group,h, has characteristics which make it closely related to soil group bh. These soils are most often encountered in Island segments IV and V. They are developed on Felsenmeer covered uplands which are presently stable. The profiles are characterized in the upper few inches by a large amount of coarse skeleton, see Appendix A, around which brittle, somewhat blocky or peaty structured Sapric organic material fills in. Below this horizon the amount of Sapric organic material decreases sharply and the amount of void space and mineral soil both increase. Void space may amount to 50% of the volume down to about 12 inches. Below this depth sandy loam or sandy gravelly loam completely fill in around the skeleton. In the zone of void space many of the rocks have small patchy encrustations of salt. This attests to at least some periods of strong evaporation in these well drained soils. Such soils are closely related to those found in typically alpine areas.

Soil group e -- The last soil group to be separated on the Island is designated soil group e. This group is limited in extent and is developed in coarse-to-fine dune sands in crest positions near the coast and in one instance at the end of a large pond where the fetch is sufficient to allow sands to be washed up onto the shore. Such areas are characterized by excessive drainage and a tall and dense cover of *Elymus* and vetch. Soil horizon development is very poor, due primarily to the sandy texture. Organic matter accumulation is minimal in the profile. However, a rather deep litter occurs on the surface. Chemical and physical analyses have not been made for this soil.

Other soil characteristics

Volcanic ash layers

Between one and three thin mineral horizons have been described in soils of groups a_1 through b. For a given soil group the thickness and relative depth are surprisingly consistent over the Island. In the field and in preliminary reports on the Island soils, (Everett, 1967, 1968) these mineral zones were considered to be layers of volcanic ash.

Where the three horizons are fully developed the upper two are of sandy texture. They are separated from one another by 3 to 5 or more inches of peat. The third mineral horizon is not sandy and generally has the texture of a silt loam. It is separated from the mineral horizon just above (the second ash horizon) by usually only an inch or less of peat.

The upper two mineral horizons are composed individual, corroded, twinned feldspar grains, and some highly altered ortho pyroxenes. By far the largest proportion of the mineral material consists of rounded and subrounded units of clay sized, amorphous material with abundant, oriented small (45 μ) feldspar laths. Small vescicular fragments (pumice?) are also common. In general the ash is andesitic in composition and is primary, i.e., it has not been reworked.

The second ash layer is also andesitic in composition. Pumice (?) fragments are less abundant and Plagioclase feldspar laths are smaller and somewhat more corroded than in the upper layer. Pyroxenes are more abundant and all show alteration.

The third or lowest ash also appears to be andesitic but is highly weathered. There are few identifiable plagioclase crystals. Pyroxenes are few and highly altered. Pumice (?) fragments appear weathered and are heavily coated with organic material and/or iron compounds.

The depth of the ash layers* as well as the relative distance between them decreases from the a_1 soils to those of group b. This

---

* Two deeper ash layers, about 29 inches and about 40 inches occur in some a_2 profiles and appear highly weathered.

is due largely to a slower accumulation rate in group b soils as well as compaction associated with increased humification.

It is possible that ash landing on bh positions was washed or blown down slope to the a_1, a_2, and b positions which would explain its general absence in bh profiles. In any event the ash falls were light and probably had little effect on the vegetation. They were most certainly cold. Ash layers become slightly thicker in the Island's western segments which suggests a western source. If suitable dates are obtained on organic material associated with the ash layers this will prove useful in calculating the rate of organic matter accumulation in the different soil groups on the Island*. Based on texture and thin-section analyses (weathering state) alone there seems to be a significant time difference between the deposition of the lower ash and the two subsequent ones.

Soil temperature

The cool, maritime climate of the Island is the overall governing element for soil temperature. Local variations which occur between the different soil groups are governed by daily ambient air temperature, moisture, and vegetation.

The following graph shows some trends in temperature data for the major soil types. (Figure 20).

---

* Some radiocarbon dates are available but the lack of adequate published stratigraphic description precludes their use here.

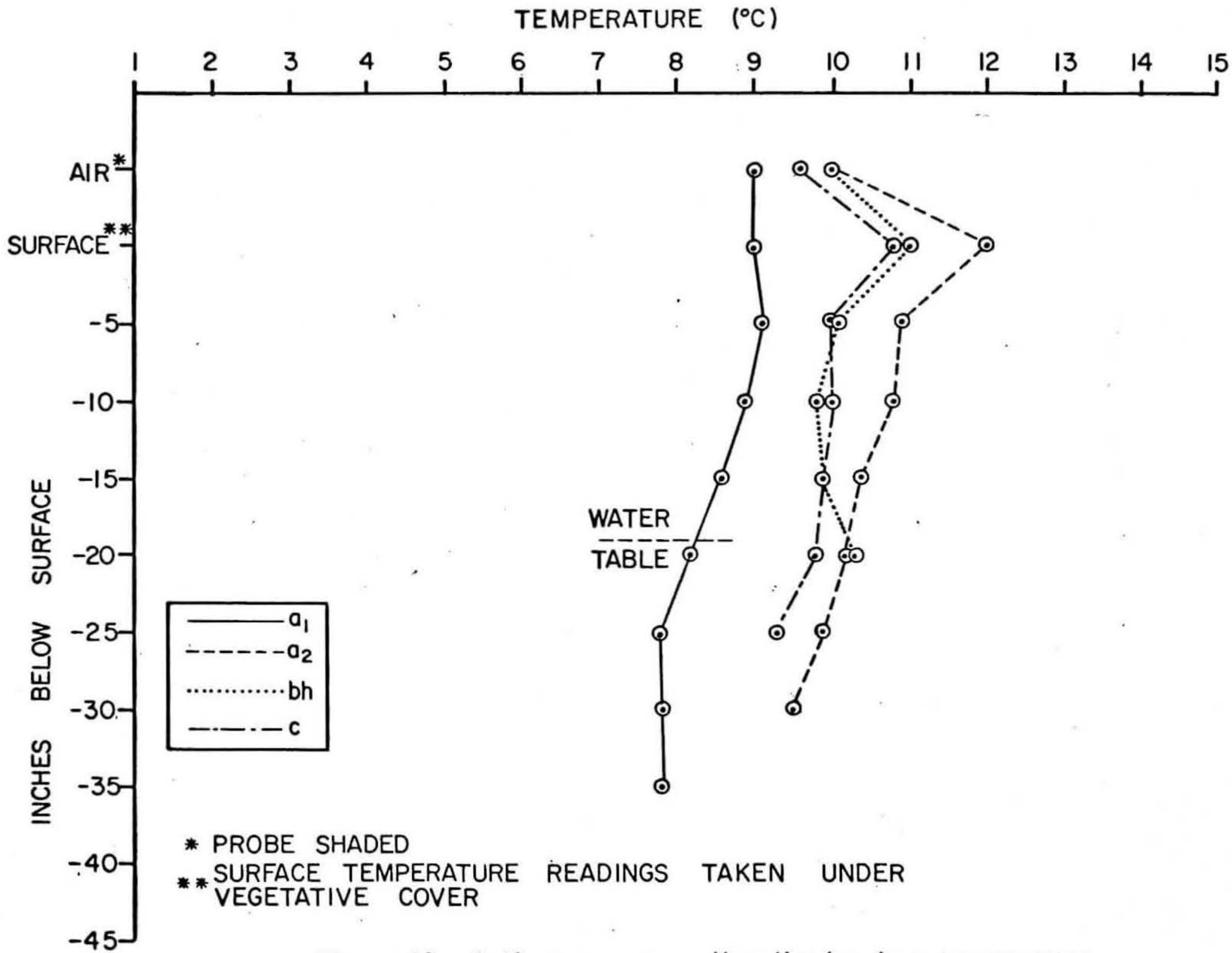


Figure 20: Soil temperature distribution in a toposequence

The time separation between readings a_1 and the other three was several hours, which accounts for the degree change in ambient air temperature. The c, bh, and a_2 soil temperatures were obtained over the space of thirty minutes, and the profiles are in toposequence. Surface temperatures of this group reflect vegetation type. All four curves reveal rather high soil temperatures to considerable depth, with a more-or-less uniform decrease with depth. The increase at the -20 inch level in soil group c and the flattening of the curves in that region in both the a_2 and bh soil groups represents a residual temperature from strong surface heating two days earlier.

The effect of soil moisture is clearly visible in the temperature distribution of soil group a_1. The presence of a water table below 19 inches probably accounts for the maintenance of uniform temperature below 25 inches. All temperatures at depth are substantially above the mean annual air temperature of the Island. Even at depths to 80 inches the soil temperature on 3 September, 1968 was close to 7° c. At this depth mineral soil temperatures generally reflect closely the mean annual temperature. The insulating effects of organic soils may substantially alter this "rule of thumb".

These relatively high soil temperatures are conducive to both chemical weathering as well as deep rooting of plants. They are also conducive to high production rates for organic matter, and to its humification as well.

Soil Moisture

Just as soil temperatures reflect differences between soil types and their position in the toposequence, so also does soil moisture to an even greater degree. It is to a large extent on the basis of soil drainage (soil moisture) and position in the toposequence* that the initial soil groupings were established for Amchitka Island. Soil moisture also is of considerable importance in predicting trafficability and fluid waste transfer. Table I presents a comparison of soil moisture values for the major soil groups in an idealized toposequence.

TABLE I

Soil Group and Geographic Position		Slope Angle	N	Range in Moisture %	Average % Moisture
a_1	Old lake beds, shallow drainage-ways, isolated upland depressions	0 - 5°	12	790 - 2640%	1256%
a_2	Upland flats, shallow swales, foreslopes	3 - 10°	61	320 - 1260%	620%
b	Lower hill slopes	3 - 33°	37	160 - 932%	354%
bh	Usually on upper hillslopes	2 - 15°	58	104 - 400%	201%
c	Crest positions	0 - 2°	13	20 - 169%	106%
e	Bluff areas (stabilized dunes)	0 - 5°	3	24 - 61%	39%

Soil moisture distribution by soil group

* Extremes based on samples from all areas of Island.

Moisture conditions in the different soil groups on the Island are quite different, Table I. However they do not fluctuate greatly from week to week, Table II. a_1 and a_2 soils appear to remain at or nearly at saturation at all times. bh soils are generally less than saturated as are b soils at least in the upper 9 to 11 inches. c group soils can be for the most part considered as unsaturated, see Table III. During and after heavy rains moisture values increase in all soils. In soil groups b and bh excess water is quickly disposed of along textural discontinuities and through a fracture system developed in Sapric horizons. Except on c anc ce soils surface run-off is negligible, yet streams react almost at once. Much of their volume increase is from water discharged to them through the soil via the fractures mentioned above, and through the already saturated a_2 and a_1 soils along the streams. After heavy rains water movement along the organo-mineral soil contact of both b and bh soils is apparent. This creates an unstable situation on moderate and steep slopes see page 79 for example.

Clay rich mineral soils, particularly those in the western segments (V and VI) of the Island, see profile AMC 125 Appendix A, have a tendency to become semi-liquid when critical moisture levels are exceeded. Several were found to display this condition under vibration with field moisture values near 40%. Past experience has shown that these levels may be reached or

TABLE II

Comparison of saturated and unsaturated moisture values for a soil toposequence. Physiographic segment III.

Soil group	Percent Field Moisture*	Percent Saturated Moisture
a_2	1160 %	1220 %
b	168 %	180 %
bh	122 %	156 %
c	208 %	276 %

* Values determined on the same day. August, 1968.

TABLE III

	Percentage of Moisture			
Date	Soil c	bh	b	a_2
7/18/68	64% *	133%	187%	1090%
7/24/68	89%	153%	213%	1233%
7/31/68	101%	149%	201%	1097%
8/7/68	72%	123%	169%	1234%
8/29/68	64%	147%	170%	1260%

Field soil moisture values for a toposequence in Physiographic segment II, Amchitka Island.

* Values in % water, dry weight basis.

exceeded many times in a single summer depending upon local weather conditions. The vescicular character of the near surface mineral soil is usually a good indication that the material may undergo liquefaction under the proper conditions.

Clay mineralogy

Clay mineralogical analyses by X-ray defraction was performed on plated clay separated from the mineral soil of several b, c, bh, and ce soils from Physiographic segments III and IV and on mineral soils under lag gravel in segment V. Initial X-ray patterns were difficult to interpret. Diffuse peaks in the 14Å region appeared on air dry analysis. After glycolation these clays expanded to 16Å ;upon heating to 500°C they collapsed to a diffuse region between 11 and 13.5 Å. This indicated an expanding lattice clay of montmorillonite type. Failure to collapse completely upon heating indicated the presence of an amorphous constituent such as organic matter (producing a diffuse peak) or interlayer Fe or Al holding the lattice apart. All samples were treated with $Na_2S_2O_4$* to remove Fe and the defractograms rerun. Iron removal enhanced the characteristic montmorillonite peak and allowed collapse to about 10 Å upon heating to 500°C.

* Sodium Dithionite (Sodium hydrosulphite)

The mineral soil horizons of typical b and bh soils showed montmorillonite to be the only clay mineral present. Based on the small number of samples analysed it appears that the relative amount of montmorillonite is 2 to 10 times as great in mineral soil horizons of group bh, than in those of group b. This may reflect greater weathering in these better drained and more oxidized soils. It may also in part account for their tendency to solifluct down slope. Slight amounts of clay sized quartz and feldspar also appeared on the defractograms.

Defractograms of mineral horizons of c and ce soils showed small amounts of clay size quartz add feldspar and only trace amounts of montmorillonite. Thus any pedogenic montmorillonite was removed by deflation. Trace amounts of Kaolinite (?) were found.

Montmorllonite was identified from a mineral soil sample taken from a terrace in Physiographic Segment IV. Terraces in this and segment V probably contain large amounts of this mineral which in part accounts for their mobility. The montmorillonite is probably derived from fault gouge (considerable in these segments) and is not pedogenic.

Soil Genesis

The soils of Amchitka Island have developed over a considerable period of time in response to poor or restricted drainage and a cool climate.

Evidence from several areas of the Island indicates that during the last glacial episode in North America (late Wisconsin) Amchitka Island supported a small, probably thin ice cap, centered on the elevated plateau of physiographic segment V. Contemporaneous with and/or subsequent to the development and disappearance of this ice cap, solifluction and the widespread development of patterned ground occurred over much of the island. A section exposed near test site E, physiographic segment IV, reveals a soil with considerable organic matter and carbonized roots buried beneath solifluction material over which a prominent boulder (lag pavement) occurs. Intermixed in the boulder pavement are silts and sands with organic matter and roots. Immediately overlying the boulder pavement is 43 inches of hemic peat (soil group b). Thus it appears that prior to the establishment of the present organic soil cover at least two phases of soil development and solifluction have occurred. There is no indication that the previous soil phases were similar to the present one, (a pollen profile of this exposure is being prepared which may show vegetation trends).

The presence of a boulder or lag pavement is common beneath most of the organic soils on the Island and probably is a remnant of the last cold period. This may not apply in segment I, see page 12. Organic matter or organic stain is frequently associated with the boulder pavement or where a pavement is lacking just above the mineral soil-peat contact suggesting a paleo soil. The presence of B_2 and B_3 horizons which are occasionally indurated lend some support to this. However it is a common occurrence in organic soils to have soluble iron-organo compounds and iron hydroxides precipitated at textural discontinuities resulting in a dark, greasy feeling organic horizon resembling a paleo soil.

What change in conditions brought about the shift from a frost climate and its attendant ground patterning and solifluction to one of peat accumulation can at the moment only be guessed at. What ever the cause, a decrease in the quantity of drainage had to have taken place. This may have resulted from a shift in base level (in this case either a rise in sea level or subsidence of the Island) or from the establishment of permafrost on the Island. The establishment of permafrost with the last cold period and its persistence into a subsequent wet and cool period would have provided the conditions necessary for the establishment of a blanket bog. Once established the bog would tend to sustain conditions necessary for its existence, until natural, climatic change, island uplift, or manmade (construction) changes alter them.

Several approaches have been taken to determine the age and rate of formation of the Blanket bog. These have involved determination of the age of the "Paleosoil" in several areas by radio-carbon methods. This approach of course presupposes that the material being dated is indeed a paleosoil and was formed in situ. Several dates of this horizon taken in connection with archaeological investigations (R. Sense, Personal Communication) range from 6650 B.P. to 9810 B.P. Other estimates based upon the observed present rate of organic accumulation, i.e., 1 inch/100 years for soil group a_2 indicate ages between 2500 B.P. to 5000 B.P. Whichever set of dates proves most correct it is certain that there is a wide range over the island. Profiles indicate soils in physiographic segment I may be much younger than those of other segments, approximately 1000 years based on the above accumulation rate.

The amount of deflation and solifluction taking place in segments III, IV and V in addition to the lowering of lake levels, and some drying altogether suggests a shift toward a dryer climate or increase in elevation of the Island or both.

Little can be said concerning the genesis of the mineral soils other than to restate that they are for the most part truncated soils. Some have undoubtedly undergone weathering subsequent to truncation.

Soil group h, page 64 , is restricted to the upland areas of physiographic segments V and VI. It is developed under conditions of good drainage on stabilized felseanmeer; (block fields were produced during the last cold period). It is therefore an old soil and represents the fullest expression of a zonal soil on the Island.

Group e soils are all immature.Recent stabilization of dunes (?) and continued aperiodic influxes of sand prevent the establishment of a genetically significant profile (they are analogous to alluvial soils).

Natural Soil Stability

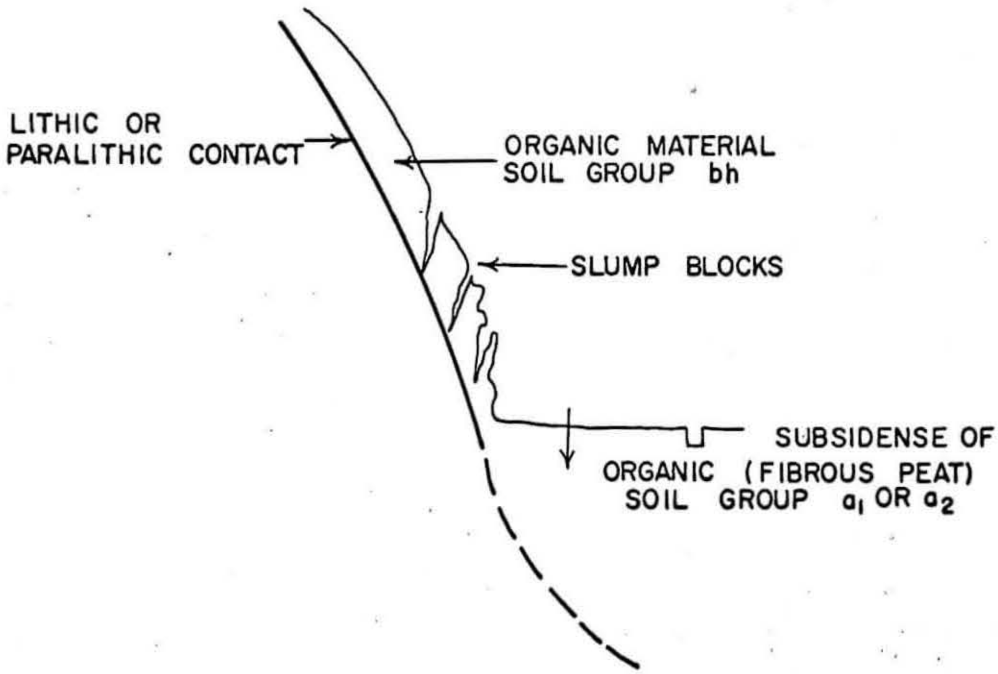
Landslides

Under natural conditions the soils of Amchitka Island appear to be generally stable. The organic composition and heavy and relatively deep-rooted vegetation combine to produce a high degree of natural stability in the soil. This is especially true in Island segments I and II.

On slope situations the pronounced textural discontinuity between the mineral soil and the overlying peat, in addition to acting as an avenue for water movement (lubrication), is a natural slide surface. In certain areas in segments III through VI the movements may be slow and discontinuous (Solifluction), Figure 23. Occasionally they may become rapid and catastrophic as in the vicinity of Test site F where small debris slides have developed in the last 20 years on steep slopes (36°) facing the Bering Sea. In general these slides have a bulbous plan, narrowing downslope and are developed in soils of group bh. The slide plane ranges in depth between 17 and 30 inches and occurs between the mineral soil and organic horizons. Careful examination of the area indicates that this type of slide has occurred over a considerable period of time and that nearly all portions of the slope have been affected. In all but the most recent cases a new vegetation cover has developed. Possibly the fine, organic-rich silt washed from the headwall over the exposed mineral soil provides a medium for growth.

A somewhat different type slide occurred on the bluffs immediately south of "CP" camp, on the extreme west end of the Island. This slide appears to have developed as a result of water movement along the base of b and bh soils becoming locally impounded in a slight structural depression on the slope (old beach line?). The subsequent increase in head of the peached water table initiated a rapid debris slide which sent large blocks of organic matter (b and bh soil) out onto a raised beach. Headward sapping from the initial head wall has extended the slide area upslope and has resulted in deposition of mineral material over the organic blocks downslope.

Other forms of natural sliding involve removal of the soil



RELATIONSHIP OF SOIL GROUPS a_1 AND bh TO STREAM BANK SLUMPING.

Figure 21

of the slope, either by stream or wave action or by subsidence of adjoining thick organic soils, i.e. a soils, see Figure 21.

This latter process seems relatively common in the head water areas of small streams in Island segments II and III. Movement of such unstable material is being monitored near Test site B to establish the rate of movement prior to possible test related disturbance.

Other small debris slides or their traces are common along the steep arête slopes bounding the cirque-like basins of physiographic segment V. Many of these appear to have developed due to overloading the top of the slope with mineral soil moving off by solifluction. Some slumps or debris slides have developed since the last ash was deposited as their debris covers b - bh soil with an ash sequence. Vegetation has become re-established.

Massive landslides (slump) occur in the Chitka Cove area. They are thickly mantled with b and bh soils and appear to be quite old. The slumps are of the block type. The slide plane is curved and probably intersects bedrock. They appear to be composed of local bedrock which has been highly altered by faulting. Some marine silts may also be involved.

The unique and rumpled topography seaward of the slump blocks suggests that earthflow occurred contemporaneously with the slump. Earthquakes or perhaps marine under cutting may have caused the slump.

Faulting and rock alteration appear to contribute much to the active and highly eroded area of sea cliffs between Cyril Cove and Chitka Point.

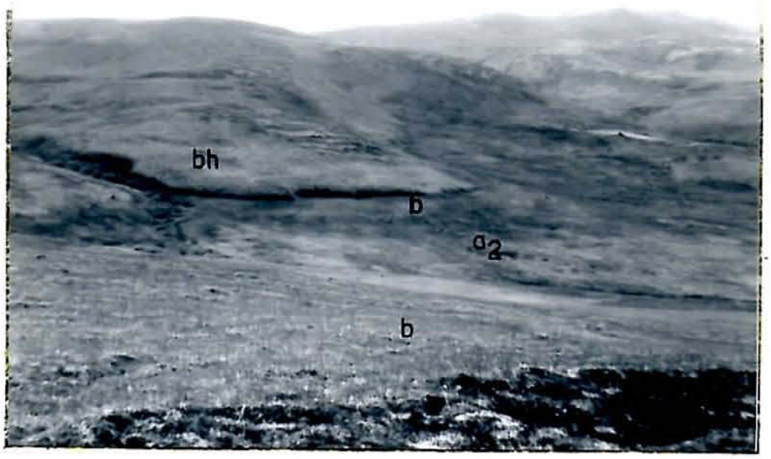
Other cliffed areas of the coast have curtains of organic material resting on or hanging over bedrock or occasionally sands and gravels. Solifluction from behind the cliffs probably accounts for some material moving over them. Undercutting by strong on-shore winds accounts for a considerable portion of it. Despite this, in some cases unsupported and nearly vertical attitude of the organic mat, its fibrous organic composition gives it surprising resistance to the forces of gravity and wind.

Solifluction

Solifluction has already been mentioned in this section, page 79 . Although it is a far less rapid form of mass wasting it is as far as Amchitka Island is concerned probably the most common and impressive form of instability.

Prominent solifluction lobes are developed in all physiographic segments. The break in slope at the terminus of the lobe usually represents the boundary between bh and b soil groups, Figure 18. In physiographic segment IV waves of unstable gravel and organic rich mineral soil can be found moving off the higher areas, leaving conical bedrock mounds and flattened summits, Figure 22. The edge of this wave of moving debris forms a roll of turf one to

<u>Figure 22</u>: Flattened summits feeding debris downslope. East end of physiographic segment IV. Soil types labeled by letter designation.



<u>Figure 23</u>: Solifluction sheet. Note contour terraces. Soil types labeled.

three feet high which in many cases completely encircles the hill. Succeeding waves are expresed both as continuous and discontinuous lobes. Cross section excavations suggest these features are formed by slow, saturated flow of mineral soil into and beneath the organic mat. In the more eastern physiographic segment of the Island the solifluction sheets appear either to be arrested or very slow in their downslope movement.

Westward from physiographic segment III solifluction terraces are commonly associated with the layer solifluction sheets.

The terraces appear to be of two types: 1) steplike, terraces covering part or all of a slope (size angle 10° +) and oriented normal to or slightly oblique to the slope direction. These probably formed on active solifluction sheets where the organic mat was rifted by movement. Subsequent wind erosion has accentuated the terrace form. These terraces are best developed in segment III, Figure 24. 2) A second group of terraces characterizes the western physiographic segments. They are the turf-banked terraces, Figure 25. Individual terraces may extend nearly along the contour for several hundred feet, some eventually coalescing with stripes extending downslope. The risers range between 2 and 5 feet high and may be completely covered with vegetation, usually Empetrum nigrum. The riser slope is usually less than 20°. It is frequently breached by tongues of cobbles and boulders with fines which have moved off the nearly flat terrace tread. The tread surface

Figure 24: Wind eroded terrace associated with solifluction sheet, see Figure 23.

Figure 25: Turf-banked terraces, note debris tongues breaching risers,soil groups labeled, physiographic segment IV.

is usually broad, up to 10 feet and covered with lag gravel 1 to 5 inches in diameter. Its surface displays the combined effects of wind and frost action in the form of well-developed, small, sorted stripes and/or miniature sorted nets. These features are very active and typify c - ce soil situations. The c soil type developed on the vegetation covered riser, the ce on the treads. The pattern though dynamic is probably rather stable in plan.

Deflation

The effects of deflation have already received some consideration under the discussion of soil groups c and ce. All areas mapped with that designation are to one degree or another subject to strong wind action. Deflation first becomes a serious erosional consideration in physiographic segment III and increases westward culminating in the extensive deflation pavements of segment VI. Once the organic mat is breached for any reason it begins to dry and becomes susceptible to wind action, Figure 26. It is not at all certain how quickly if ever a deflated area recovers a cover of vegetation. Once the mineral soil is exposed frost hearing becomes a consideration in the success of pioneer vegetation. Lupinus nootkatensis is commonly found growing on deflation pavements. In some areas, i.e., south of test site D and near test site C both the vegetation and the state of soil development suggest recovery of a deflated area. On the upland

Figure 26: Soil group bh undergoing wind erosion. The result is the production of a lag gravel surface. Physiographic segment III, near test site C.

lag gravel surfaces in segment VI scattered Lupinus n and Salix sp. act as sand traps and result in mounds, some covered with vegetation others being eroded. Once a lag gravel surface has become established the underlying mineral soil if not severely disturbed by frost action is protected from further intense deflation.

Test and Test-related Effects

Vehicular Traffic

The trafficability of the Amchitka Island soils, with few exceptions, is poor. Offroad travel on the Island is restricted to tracked vehicles with low-bearing pressures. Under most conditions the single pass use of such equipment will damage the vegetation cover. However, under high moisture conditions (after rains) even a single pass over slopes with a_2 or b soils may result in breaching of the vegetation and exposing the underlying organic material. Several passes using the same track will seriously damage the vegetation and compress the underlying peat, resulting in ponding. This applies to soil groups a_1, a_2, b and areas mapped a_1/a_2, a_2/b and b/a_2. These scars are slow to heal and in some cases a_2 areas may be turned into areas whose surface appearance is similar to a_1. It is doubtful, with such drainage changes, that these areas will ever revert to their original condition. Extensive areas of this character occur in segment II and have been mapped with a suffix d to designate them as disturbed. Because soil groups b and bh can both occur on rather steep slopes, they are vulnerable to repeated single track passes. Morphologically they undergo less compaction but the unequal distribution of bearing pressure from an ascending vehicle can cause rifts in the vegetation and upper horizons of the organic soil. Once exposed, desiccation and deflation, as well as surface wash, attack the organic mat, and in some cases expose the underlying mineral soil which is easily eroded by running water. Once the mineral soil is so exposed, the damage is probably irreparable.

Soil group c is under most conditions resistant to vehicular traffic, particularly low-bearing-pressure tracked vehicles. Even these soils, located in topographically favorable positions, can be disturbed during periods of high soil moisture. Wheeled vehicles can be used on such soils during dry periods. However, even though moisture valves near the surface may be reduced, they are likely to remain relatively high in the finer-grained deeper horizons with the result that deep ruts can be made in the surface. Under such conditions wind erosion becomes active in and along the sides of the ruts.

Heavy, tracked vehicles can be used over most of the Island but surface destruction is likely to result from even one pass, especially in areas of a_1. a_2, and b soils.

Site construction activities

Major construction activities such as the building of roads have required extensive stripping of the organic mat and exposing of mineral soil and fractured bedrock. Natural restoration of such areas to their pre-disturbance condition is not likely. Dying and deflation will continue to expose bedrock or foster the development of a lag gravel concentrate. Subsequent growth of pioneer vegetation, principally Lupinus n and perhaps some grasses will provide a measure of natural stability.

The construction of drilling platforms which require the emplacement of many hundreds of tons of borrow on the organic terrain of course destroys that area and the areas immediately adjacent. Construction of such platforms and the placement of settling pits without regard to the characteristics of the underlying organic soils results in mudflows such as occurred in late August 1968 in connection with test site E. This slide involved soil group a_2 on a slope near a drainage head. The profile consisted of 42 inches of peat (hemic) over a lag gravel. At the time of sampling several days after the slide the fine material associated with the lag gravel was still very wet (64% moisture). It seems likely that the increased weight of the drilling platform and the leakage from settling pits located immediately upslope from the slide provided the necessary conditions for slippage at and just below the textural break in the profile.

The resultant rapid mudflow completely filled the adjacent stream valley and moved to the sea.

What effects this pollution had on nearshore marine life I cannot assess. The damage to the drainage basin is considerable. In time the mineral and organic debris will be removed from the stream valley, however continued erosion of the slide area can be expected.

Drilling fluid leakage from settling pits at other test sites on the Island may in fact be related to the soil types which are intercepted by the pits. The pit at test site B intercepts both soil groups a_2 and bh. It is possible that near-surface leakage occurred between the mineral soil-organic contact. The fluid was probably moved through the a_2 soil under a head and into the nearby drainage. Had the settling pit not intercepted the porous and saturated a_2 soils leakage may not have occurred. Fluid passage through these soils may be so rapid that conventional sealing agents are flushed out along with the drilling fluid.

Road construction in physiographic segments IV, V and VI have encountered some of the easily fluidized mineral soils. The usual results have been differential settling and rutting under traffic.

Camp construction has for the most part been confined to areas already highly disturbed and does not appear to have further affected them.

Possible test effects

The effects of testing will, as far as the soils and geomorphic features are concerned, be confined to a radius of a few miles of the test site. Many, if not most tall, thin sea-stacks will be toppled, especially those with steeply dipping fracture planes.

The organic mat of a_2, b and bh soils may become separated from the underlying mineral soil and/or bedrock due to large amplitude ground waves. This would be particularly true if the rates of propagation or amplitudes are significantly different in the peat and mineral soil, some distance away from ground zero. In any event slippage is likely on sloping areas, especially adjacent to streams. Natural slope instability along streams near test site B is apparent. Movement grids established in April, 1968 showed no movement as of September, 1968 (Holmes and Narver, written communication). A re-survey will be made just prior to test to establish a natural rate. Movement of the organic mat has been established in Ultra Basin, several miles northwest of test site B. (Clebish, E.E.C., Personal communication). The result of such movement would be to plug portions of the drainage causing local ponding, and to expose the easily erodable subsoil.

Collapse of Karst drainage conduites and subsequent ponding or lake drainage is possible but should be minimal near test site B. It is difficult to estimate the extent or effect of disruption (collapse) of the fracture systems associated with the Sapric horizons of group b and bh soils. This may shift the drainage, particularly of group b soils to a lower category, page . Some movement of the frontal margin (roll) of bh soils may also occur. This will be more of a consideration near test sites C,D, and E.

If, subsequent to testing, a collapse crater develops at the test site, it will materially alter the drainage characteristics of the area; i.e., it will provide a new base level and result in depression of the water table. Considerable drying and subsidence can be expected in a_2 and b soils. The subsidence will be due to volume change upon oxidation. A shift in composition of the vegetation may be expected.

In the event of open air particulate venting the reaction of the surrounding soil groups may become important. It is known, for example, that soil pH affects the rate of release of radiogenic strontium to the ground water, (Himes, in press). What effect the textural, structural, and chemical differences of the horizons which characterize the different soil groups have on other radio nucleides is not known.

In sum the effects of testing will in general be proportional to the natural stability of the landscape. Thus tests contemplated for physiographic segments III through VI may be expected to be more damaging, particularly along coastal areas and near the uplands, than in other segments.

The following table provides in summary form data for the different soil groups pertinent to testing.

TABLE 2

Topographic position	Slope angle	Surface characteristics	Vegetation	Moisture	Morphology	Depth to mineral soil	Natural stability	Reaction to testing	Trafficability
a_1 old lake beds, shallow drainage ways, isolated depressions	0-5°	even, wet frequent standing water	complete; grasses and sedges	790-2640% water table between 15-20"	raw fibrous peat (Fibric)	70"+	high	slight	poor vegetation easily disturbed
a_2 upland flats, shallow swales, foreslopes	3-10°	even, wet	complete; lichens and moss	320-1260% water table 40"+	moderately decomposed peat (Hemic) fibrous peat in lower part; gelatinous mat upper 1"	40"+	high	slight; possibly some cracking, subsidence	very poor destruction of gelatinous mat & vegetation, drying & erosion of underlying peat
b lower hill slopes	3-33°	even to slightly hummocky or ribbed	complete; grasses and moss	160-932% usually no water table in organic section	alternating layers of Hemic peat and Sapric peat; multiple thin ash layers; coarser peat near bottom	70"+	high to low	slight to moderate; sliding over mineral soil on steep slopes; subsidence due to drainage.	moderate on lower slopes, some destruction of vegetation. very poor to impossible on slopes 20°; severe disruption of surface
bh usually in upper hillslopes	2-15°	very hummocky, often appears to be overriding b or a_2 soils	complete; similar to b	104-400% no water table in organic section	Hemic and Sapric peat; sapric horizons may be fractured, plinthite pan may occur above mineral soil	28"+	medium; prone to wind erosion, natural solifluction	slight to extreme; sliding over mineral soil; structural collapse may alter internal drainage	good little disturbance if dry; if organic mat breached, may erode

TABLE 2 (continued)

Topographic position	Slope angle	Surface charact-eristics	Vegetation	Moisture %	Morphology	Depth to mineral soil	Natural sta-bility	Reaction to test	Trafficability
c crest positions	0-2°	even to slightly hummocky	lichens, flowering plants	20-200% no water table	Hemic mineral soil may be indurated for a few inches below peat contact	12"+	high to medium; prone to wind erosion	slight, where in terraces; cracking may cause breaching of peat and erosion of mineral soil	good rutting in wet weather
e bluff areas	0-5°	uneven	*Elymus* sp. grass	10-50% no water table	loose sand	---	high	slight, may slide on steep slopes	poor vegetation easily disrupted

REFERENCES

Amundsen, C., and Clebsch, E.E.C. 1969. The Plant Ecology of Amchitka Island: Interim Report. pp. 2.

Everett, K.R., 1967; Evaluation Report, Battelle Memorial Institute.

Everett, K.R., 1968; Geomorphology and Pedology of Amchitka Island Annual progress report. p. 80. Unpublished.

Farnham, R.S., and Finney, H.R., McKinzie, W.E., 1966; Histosols: An Approximation to Classification. Unpublished manuscript.

Himes, F.L., and Mangaroo, A.S., Retention of Strontium by Soil (In Press)

Johannesson, B. 1960; The Soils of Iceland: University Research Institute, Dept. of Agriculture Reports, Series B, No. 13, p. 140.

Kellogg, C.E., and Nygard, I.J. 1951; Exploratory Study of the Principal Soil Groups of Alaska: U.S. Dept. of Agriculture, Agricultural Monograph No. 7 P138 (pp. 34-42).

Powers, H.A., Coats, R.R., and Nelson, W.H. 1960; Geology and Submarine Physiography of Amchitka Island, Alaska: U.S. Geological Survey Bull. 1028-P., pp. 521-554.

Rieger, S., Wunderlich, R.E., Link, E.G., Backer, A.D., Paschall, A.H., Rice, C.M., and Larramendy, W.L. 1960; Soil Survey and Vegetation, Northeastern Kodiak Island Area, Alaska: U.S. Dept. Agriculture Soil Survey Series, 1956, No. 17, p. 46.

Soil Survey Staff, 1960; Soil Survey Manual: U.S. Dept. of Agriculture, Agriculture Handbook, No. 18, pp. 170-171.

Ulrich, H. 1946; Morphology and Genesis of the Soils of Adak Island, Aleutian Islands: Soil Science Soc. America Proceedings, Vol. 11, pp. 438-441.

Appendix A

Description of representative soil groups

(See soils map for location of profile.)

SOIL GROUP a_1

AMC 79

Vegetation:	Carex sp., Empetrum n., minor amounts of Cladonia sp.
Topography:	Valley bottom, slope angle 0°.
Microrelief:	Flat or having small hummocks 1-2 inches high.
Drainage:	Poor to very poor; periodic standing water; water table 19 inches on 4 September 1967.

Depth	Horizon	
0-1"		Mat of living mosses.
1-3"	Oa1	black, 5 yr 2/1*, Sapric peat; 25-30% fiber; slightly sticky. Lower boundary abrupt.
3-5"	Oe1	dark reddish brown, 5 yr 3/2, Hemic, mostly fine fibrous peat intermixed. Lower boundary abrupt.
8½-11"	Oi1	dark brown, 7.5 yr 3/2, Fibric, largely medium and coarse fibrous peat. Lower boundary clear.
11-21½"	Oi2	dark brown, 7.5 yr 3/2, Fibric, color appears slightly darker than above. Lower boundary abrupt; water table at 19 inches.
21-23"	Oi3	very dark brown, 7.5 yr 2/2, Fibric, coarse fibrous peat. Lower boundary abrupt.
23-24"	Oe2	dark brown, 10 yr 3/3, Hemic, loamy sand, slightly sticky. Lower boundary abrupt. (Probably an ash layer.)

---

* See glossary, Appendix C.

Depth	Horizon	
24-28½"	Oi4	dark brown, 7.5 yr 3/2, Fibric, medium fibrous peat. Lower boundary gradual.
28½-35"	Oi5	dark brown, 7.5 yr 3/2, Fibric, coarse fibrous peat; some mineral material.
35-43"	Oi6	very dark brown, 7.5 yr 2/2, Fibric, coarse to very-coarse fibrous peat.

SOIL GROUP a_2

AMC 63 Cloudy Amchitka Island 1967

Vegetation: Antitrichia c., Empetrum n., Reindeer lichen (Cladonia), scattered Carcx, a general brown or rust-brown appearance.

Topography: Rounded hill - approach slope, slope 5°, S-SE exposure.

Microrelief: Slightly uneven, low broad hummocks, no pattern, 6-12 inches.

Drainage: Very poorly drained.

Depth	Horizon	
3-0"		Mat of living vegetation.
0-1"		dark yellowish brown 10 yr. 4/4, to 10 yr 2/2 very dark brown organic silt (wet) forms a gelatinous layer under vegetation carpet; roots common. Lower boundary abrupt.
1-4"	Oe1	dark yellowish brown (wet), 10 yr. 3/4; dark brown (squeezed), 7.5 yr. 3/2; hemic peat; roots abundant. Lower boundary gradual.
4-10"	Oe2	dark brown - brown (wet), 7.5 yr. 4/2; dark yellowish brown (squeezed), 10 yr. 3/4; hemic peat; less coarse fibrous material than 1-4"; roots abundant. Lower boundary abrupt.

Depth	Horizon	
10-11"	u*	Light olive brown , 2/5 yr. 5/4; medium sand or loamy sand; fine roots common; massive. Lower boundary abrupt.
11-18"	Oa1	very dark greyish brown (wet), 10 yr. 3/2; very dark greyish brown (squeezed) 10 yr.3/2; peaty silty clay loam, a few sand grains or nodules; rubs down with moderate ease; considerable coarse fibrous material; roots common; lower boundary gradual.
18-22"	Oe3	very dark greyish brown (wet), 10 yr. 3/2; dark brown (squeezed), 7.5 yr. 3/2; hemic peat
22-27½"	Oe4	very dark greyish, 10 yr. 3/2; hemic peat; massive. Lower boundary abrupt.
27½ 30"	u	2.5 yr. dark greyish brown 4/2 ; very fine sand and silt with some mixed fibrous peaty material; massive. Lower boundary abrupt.
30-42"	Oi2	dark brown (moist), 10 yr. 3/3; very dark greyish brown (squeezed), 10 yr. 3/2, Fibric peat. Lower boundary clear.
42-48"	Oe5	dark brown (wet), 10 yr. 3/3; very dark greyish brown (squeezed), 10 yr. 3/2; Fibric peat. Lower boundary clear.

* mineral horizon

Depth	Horizon	
48-54"	Oi3	dark brown (moist), 7.5 yr. 3/2; very dark greyish brown (squeezed), 10 yr. 3/2; Fibric peat. Lower boundary clear.
54-60"	Oi4	very dark greyish brown (moist), 10 yr. 3/2; very dark greyish brown (squeezed), 10 yr. 3/2; Fibric peat. Lower boundary not observed.
63-66"	u	yellowish brown, 10 yr. 5/4; very fine sandy loam; few organic fragments. Upper and lower boundaries abrupt.
60-70+"	Oe6	very dark greyish brown (squeezed), 10 yr. 3/2; Fibric peat. Lower boundary not observed.

SOIL GROUP a_2

AMC 125 Cloudy Amchitka Island, 1968

Vegetation:	*Carex sp.*; *Empetrum nigrum*; *Cladonia pacifica* and *ssp.*; *Rubus sp.* Coverage 100%.
Topography:	interfluve area.
Microrelief:	Vegetation hummocks (tufts) to 12" and occasional conical vegetation mounds 3 to 4 feet high.
Drainage:	Poor.

Depth	Horizon	
2½-0"		Mat of living vegetation
0-1½"	Oa1	Dark reddish brown, 5 yr. 2/2. sapric peat, 5% living roots; wet; slightly granular and friable.
1½-6"	Oe1	Dark brown, 10 yr 3/3, hemic peat, fiber content 60% uncrushed, 25% crushed. Lower boundary clear, abrupt.
6-7"	Oe2	Dark brown, 10 yr 3/3, hemic peat; fiber content 50% uncrushed 5% crushed; volcanic ash 30%+. Lower boundary abrupt, even.
7-16½"	Oi1	Very dark brown to dark brown, 10 yr 2/2-3/3 coarse fibric peat; fiber content uncrushed 80%; 30% crushed. Lower boundary clear to abrupt, even.

Depth	Horizon	
16½-17½"	Oe3	Dark brown, 10 yr 3/2, sandy hemic peat (ash); fiber content; 60% uncrushed, 20% crushed. Lower boundary abrupt, even.
17½-18½"	Oi2	Dark brown, 10 yr 3/3, coarse fibric peat; fiber content 70% uncrushed, 30% crushed. Lower boundary abrupt, even.
18½-20"	Oe4	Dark brown, 10 yr 3/2 very fine sandy coarse hemic peat (ash); fiber content 40% uncrushed, 15% crushed. Lower boundary abrupt, even.
20-28"	Oe5	Dark brown 10 yr 3/2-3/3 coarse hemic peat; fiber content 85% uncrushed, 20% crushed. Lower boundary gradual.
28-35"	Oe6	Dark brown, 10 yr 3/4, and very dark brown, 10 yr 2/2, fiber content 50% uncrushed, 10% crushed; slightly sticky. Lower boundary clear, even.
35-41+"	Oi3	Dark brown, 10 yr 3/3, coarse fibric peat; fiber content, 90% uncrushed, 30% crushed.

SOIL GROUP b

AMC 59

Vegetation:	Carex sp., moss (Antitrichia c.) Lichen, grasses similar to AMC 58 except grasses are more numerous.
Topography:	Hill slope 15°, facing southeast.
Microrelief:	Slope smooth and uniform.
Drainage:	Poorly to moderately well drained.

Depth	Horizon	
3-0"	01	Mat of living vegetation.
0-2"	Oe1	Dark reddish brown (wet), 5 yr. 2/2; black to dark reddish brown (squeezed), 5 yr. 2/N-2/2; hemic peat with some fibrous material composed mostly of dead roots and stems; massive; very moist to wet; roots abundant. Lower boundary clear.
2-6"	Oa1	Very dark brown, 10 yr. 2/2; sapric peat; somewhat loose; breaks to weak coarse aggregates; roots abundant. Lower boundary abrupt.
6-7"	Oa2	Black, 10 yr. 2/1; sapric peat; breaks to moderate, coarse angular blocky; roots plentiful; lower boundary abrupt.
7-8"	u	Dark greyish brown, 10 yr. 4/2, 4/3, dark loamy fine sand (ash); massive; roots few to common. Lower boundary abrupt.

AMC 59

Depth	Horizon	
8-12"	Oa3	Dark reddish brown, 5. yr. 2/2; sapric peat; massive; tends to fracture obliquely downward, some fractures reach surface, many reach 30+", organo silt flows along fracture planes; abundant fine roots; larger roots common. Lower boundary abrupt, pendant in fractures.
12-15"		General color dark greyish brown, 10 yr. 4/2 with flecks of dark reddish brown, 5 yr. 2/2; sapric peat with nodules; slightly indurated; fractures extend through horizon and account for some of the 5 yr. 2/2 coloration. (Plinthitic zone?). Lower boundary clear, uneven.
15-25"	Oa4	Dark brown silt loam 10 yr. 3/3 with flecks of 10 yr. 6/8 light red bands of 10 yr. 2/2 very dark brown finely flecked with 10 yr. 6/8 light red; bands (several) 1/2" thick; horizon vesicular; massive; roots plentiful to few; Lower boundary abrupt.
25-27(½)"	Oa5	Black to dark reddish brown , 5 yr. 2/N-2/2; sapric peat; massive; breaks to moderate; medium angular blocky; roots absent; lower boundary abrupt.

AMC 59

Depth	Horizon	
27 (27½)- 32+"	B2	Yellowish brown 10 yr. 5/4--5/6 ; silt loam with granules and rocks; massive; crushes to weak, coarse aggregates.

SOIL GROUP b (Sandy phase)

AMC 104 | Partly Cloudy | Amchitka Island, 1968

<u>Vegetation</u>: <u>Carex</u> <u>sp</u>., grasses. <u>Empetrum</u> <u>nigrum</u> moss, scattered <u>Chrysanthemum</u> <u>arcticum</u> and <u>Pedicularis</u> <u>chamissonis</u>. Coverage 100%.

<u>Topography</u>: Northeast facing slope just off upland surface. Slope angle 15°.

<u>Microrelief</u>: Uniform, even.

<u>Drainage</u>: Moderately well drained.

Depth	Horizon	
2-0"		Mat of living vegetation
0-2"	Oe1	Very dark brown 10 yr 2/2 hemic peat. Uncrushed fiber 20% crushed 5%. Approximately 10% granules. Horizon somewhat loose and friable. Fine roots abundant. Lower boundary clear, even.
2-4"	Oa1	Dark brown 7.5 yr 3/2 sapric peat. 20% + mineral granules 1/32 - 1/16" moist; massive; crushes to weak, medium angular blocky units; Lower boundary clear, even.
4-9"	Oa2	Dark brown 10 yr 3/3 fine gravelly to coarse sandy loam. sapric granules 1/32 - 1/16"

Depth	Horizon	
4-9" (continued)	Oa2	Organic matter content 10-15%; massive, brittle crushes to weak, moderate angular blocky, occasionlly weakly platy. Fine roots plentiful. Lower boundary clear, smooth.
9-14"	A3	Dark brown 7.5 yr 3/2 fine granular silt loam; massive, moist slightly brittle; crushes easily to strong, coarse, subangular blocky to weakly peaty units. 7.5 yr 6/8 flecks of oxidized iron around roots, structural units and weathered granular mineral material. slightly vesicular; fine roots common. Lower boundary clear, even.
14-16"	A31	Dark brown 7.5 yr 3/2 loam; approximately 10% organic matter; moist; slightly brittle; crushes to strong, medium angular and subangular blocky units; granules are absent; fine and medium roots are common. Lower boundary abrupt, even.
16-18"	A32	Dark brown 10 yr 3/3--3/4 loam or silt loam; massive; crushes to strong to moderate, medium subangular blocky units. Mineral granules less than 1% completely weathered to 7.5 yr 7/6--6/8; roots few. Lower boundary abrupt, even.

Depth	Horizon	
18-21"	B1	Very dark grey brown to dark brown 10 yr 3/2-3/3 silt loam; massive; slightly brittle; crushes to moderate, medium, subangular blocky units; granules absent; roots few. Lower boundary abrupt, even.
21-25"	B12	Dark yellowish brown 10 yr 3/4 loam; massive; slightly brittle; crushes to moderate, coarse, subangular blocky units; vesicular; mineral granules less than 5%, most completely weathered. Lower boundary clear, somewhat uneven.
25-29"	B22	Dark reddish brown 5 yr 3/4 granular loam; very moist; massive; slightly indurated; crushes to strong, very coarse to coarse angular blocky units. Occasional completely weathered cobbles surrounded by dark brown 10 yr 4/2 silt loam (weathering product of cobbles?). Lower boundary abrupt, even.
29-33+"	B23	Dark brown 7.5 yr 4/4 granular sandy loam; very moist; vesicular, vesicules have fine silt coatings. horizon massive; moderately indurated, moderately platy; crushes to very strong, coarse to very coarse angular blocky units. Mineral granules are mostly decomposed. roots absent.

SOIL GROUP b

AMC 108 | Cloudy | Amchitka Island, 1968

Vegetation: *Empetrum nigrum*; grasses, *Carex sp.*, *Cladonia ssp.* Coverage 100%.

Topography: Southeast-facing slope, length 30 feet, slope angle 14°.

Microrelief: Slight hummocks of vegetation 2-12".

Drainage: Poorly drained. (Midslope position)

Depth	Horizon	
2-0"		Mat of living vegetation.
0-2"	Oe1	Very dark brown 10 yr 2/2 hemic peat, wet gelatinous; coarse and fine roots abundant. Lower boundary clear, even.
2-4½"	Oa1	Very dark brown 10 yr 2/2 sapric peat; massive; wet. Structureless when wet; moderate, medium to coarse subangular blocky when dry; fine roots abundant. Lower boundary clear, even.
4½-5½"	Oa2	Black 10 yr 2/1 sapric peat, massive; very moist; very slightly brittle; crushes to moderate strong granular structure; fine roots abundant. Lower boundary abrupt, even.

AMC 108

<u>Depth</u>	<u>Horizon</u>	
5½-6½"	u	Dark brown 10 yr 3/3 fine sandy loam (volcanic ash). Organic matter exceeds 20%; massive, crushes to weak, coarse to medium angular blocky to subangular blocky structure, fine roots plentiful. Lower boundary clear even.
6½-8"	Oa3	Black 10 yr 2/1 sapric peat, moist; massive; slightly brittle, crushes to weak, medium to coarse subangular blocky units; fine roots plentiful, many show oxidation coatings. Lower boundary clear, even.
8-10"	Oa4	Very dark brown 7.5 yr 2/2 sapric peat; massive, breaks to moderate, medium subangular blocky structure; fine and medium roots abundant; oxidation coatings as in above horizon. Lower boundary abrupt, even.
10-10½:	u	Very dark greyish brown 10 yr 3/2 fine sandy loam (volcanic ash); massive; breaks to weak, medium angular blocky units; fine roots plentiful. Lower boundary abrupt, ruptic.
10½-11"	Oa5	Black 7.5 yr 2/N sapric peat; massive; moderately brittle; crushes to strong, coarse angular blocky units. Yellowish red 5 yr 5/8 flecks and root coatings; fine roots plentiful. Lower boundary abrupt, even.

AMC 108

Depth	Horizon	
11-13"	u	Dark yellowish brown 10 yr 4/2 silt loam (volcanic ash); massive, breaks to strong, coarse subangular blocky to very weakly platy units. Numerous red 2.5 yr 4/8 root casts; dark red 2.5 yr 3/6 ped coatings; fine and medium roots abundant; Lower boundary abrupt, even.
13-14½"	Oa6	Black 10 yr 2/1, sapric peat; massive; moderately brittle; crushes to strong, medium to coarse subangular blocky and granular units. (Horizon is very weakly friable). Numerous red 2/5 yr 4/6 root casts; fine roots plentiful. Lower boundary clear, even.
14½-18"	Oa7	Very dark greyish brown 10 yr 3/2 sapric peat; massive; very slightly platy; breaks to strong, coarse angular and subangular blocky units; slightly vesicular; tendency to vertical fracture; 20% fine and very fine sand; numerous red 2.5 yr 4/6 root casts to 1/16" thick; reddish brown 5 yr 4/4 mottles; fine and medium roots plentiful. Lower boundary abrupt, even.
18-22"	Oa8	Black 7.5 yr 2/N sapric peat; massive to weakly friable or platy; slightly vesicular; crushes to strong, coarse and very coarse angular and

AMC 108

Depth	Horizon	
18-22" (continued)	Oa8	subangular blocky units; strong vertical fracture. Fracture walls are strongly vesicular, mottling much reduced; roots common; oxidation casts few. Lower boundary abrupt, uneven.
22-26"	B2	Dark greyish brown to brown 10 yr 4/2-4/3. Loam; massive; slightly vesicular; tendency to vertical fracture, weakly platy; crushes to very strong, coarse angular blocky structures. In-fill around boulders up to 3 feet in diameter. Slight mottling around boulders; roots common. Lower boundary clear to gradual.
26-31+"	B23	Dark brown 10 yr 4/3 fine gravelly loam; massive; weakly indurated; crushes to strong coarse angular blocky units. Cobble skeleton 30%. Small granules rounded and highly weathered. Large boulders common.

SOIL GROUP bh

AMC 64 | Cloudy | Amchitka Island August, 1967

Vegetation: *Loiseleuria p.*, *Cladonia sp.*, especially in interhummocks depressions, grasses.

Topography: South-southeast, facing hill slope 20 feet upslope from AMC 63, slope angle 10°

Microrelief: Hummocks having a rough parallelism in a downslope direction, not well stripped, hummock relief 1-7 inches.

Drainage: Moderately well to poorly drained.

Depth	Horizon	
1-0"		Mat of living vegetation.
0-1 (2)"	Oa1	Very dark 10 yr. 2/2 sapric organic matter; massive to loose; strong, medium granular structure; high organic matter content; fine roots abundant; lower boundary abrupt.
1½(2)-4"	Oa2	Black to very dark brown 10 yr. 2/1-2/2 sapric organic matter; massive; breaks to very weak, coarse, sub--angular blocky to granular structure; roots plentiful; lower boundary clear to gradual.

AMC 64

Depth	Horizon	
4-8"	Oa3	Black 5 yr. 2/1 sapric organic matter with a few granules; massive; breaks with a coarse platyness (1/16-1/8"), also a tendency to fracture vertically (obliquely); roots plentiful; lower boundary clear.
8-12"	Oa4	Very dark brown 10 yr. 2/2 sapric organic matter with granules and some sand; moist; somewhat brittle; crushes very easily to moderate to weak granular aggregates; also has a coarse platy fracture; roots common to abundant; lower boundary clear.
12-16"	Oa5	Black to very dark brown (a slight reddish tinge apparent but does not come out in mineral) 10 yr. 2/1-2/2 silt loam with granules and pebbles; sapric organic matter; somewhat loose; breaks to strong, medium granular aggregates; also has a slight tendency to platyness; brittle; roots few; lower boundary clear.
16-19"	B22	Very dark greyish brown to dark brown 10 yr. 3/2-3/3 sandy, gravelly loam or silt loam, with large rocks; skeleton 25-40%; somewhat granular; lower boundary abrupt.

AMC 64

Depth	Horizon	
19-25+"	B23	Brown to dark-brown 10 yr. 4/3 fine loamy sand and gravel, many small gravel fragments are completely weathered; massive; slightly indurated?; tendency to develop platy structure.

SOIL GROUP bh

AMC 114 Clear Amchitka Island

Vegetation:	Cladonia pacifica and ssp; Thamnolia vermiculares ; small amount of Empetrum nigrum. Coverage 100%.
Topography:	Interfluve area, physiographic segment I.
Microrelief:	Alternating depressions and hummocks , 12 to 20 inches; scattered, large conical vegetation mounds.
Drainage:	Poor to moderate.
Remarks:	This profile and AMC 115 constitute a pedon* of bh soils formed on interfluve areas, a not uncommon occurrence in physiographic segments I and II. See Figure 4 and page for further detail.

Depth	Horizon	
2-0"		Mat of living vegetation.
0-1½"		Pale brown 10 yr. 6/3 gelatinous mat of decomposing Cladonia, wet. Lower boundary abrupt, uneven. Lower ¼" sandy (ash?).
1½-4"	Oal	Very dark brown 10 yr 2/2, sapric peat; massive; moist; crushes to very weak, medium angular blocky structures. 5% granular and pebbles;

AMC 114

Depth	Horizon	
4-5½" (Continued)	Oa2	pebbles are not stained; roots few. Lower boundary abrupt, uneven.
5½-12"	Oa3	Black, 7.5 yr 2/N, sapric peat; wet massive; slightly brittle; crushes to strong, very coarse to coarse angular blocky structure; fine iron hydroxide (?) concretions; gravel skeleton 70% in ½ to 3 inch range; roots are common. Lower boundary clear, uneven.
12-16"	B22	Dark yellowish brown, 10 yr 3/4 coarse sandy loam, massive, moderately indurated, weakly platy; granules and small pebbles 10-15%; roots occasional. Lower boundary clear, uneven.
16-19½:	B23	Dark brown 10 yr 3/3, fine sandy loam; massive; moderately indurated; weakly platy; crushes to strong medium, angular blocky units; granules and pebbles as above; roots absent. Lower boundary clear, even.
19½-23+"		Dark brown, 10 yr 4/3 loam, massive; breaks to moderate, coarse to medium subangular blocky units; granules less than 5%; roots absent.

SOIL GROUP bh

AMC 115 Clear Amchitka Island

Vegetation:	Empetrium nigrum; cladonia pacifica and ssp.; Calamagrostia nutkaensis; Rhacomitrium lanuginasum. Coverage 100%.
Topography:	Interfluve area, physiographic segment I
Microrelief:	Alternating depressions and hummocks, 12 to 20"; scattered, large, conical vegetation mounds.
Drainage:	Moderate.
Remarks:	See remarks under AMC 114. This profile is through hummock. Also see Figure 4 and page for further detail.

Depth	Horizon	
2-0"		Mat of living vegetation
0-2"	Oa1	Dark reddish brown, 5 yr 2/2, sapric peat; high percentage of coarse stems and roots of Empetrum n. Lower boundary clear, uneven.
2-4½"	Oa2	Very dark brown, 10 yr 2/2 sapric peat; massive to somewhat friable; very weak, coarse granular structure. Fine roots abundant. Lower boundary clear, uneven.

AMC 115

Depth	Horizon	
4½-6"	Oa3	Black, 5 yr 2/1, sapric peat; massive; moist; breaks to very weak, coarse, angular blocky units; fine roots plentiful. Lower boundary abrupt, somewhat uneven.
6-7"	Oa4	Dark reddish brown, 5 yr 2/2, fine sandy sapric peat.(ash) roots plentiful. Lower boundary clear, ruptic.
10-12"	Oa5	Very dark greyish brown, 10 yr 3/2 sapric peat, slightly brittle; breaks to weak, coarse angular blocky units; massive; contains 5% ± mineral and scattered gravel ½-1"; roots common. Lower boundary clear, uneven to ruptic.
12-15"	Oa6	Black, 5 yr 2/1, sapric peat; massive; moderately brittle; crushes to strong, medium to coarse angular and subangular blocky; occasional rounded gravel fragments ½ to 1"; roots few. Lower boundary clear, uneven.
15-22"	Oa7	Black, 7.5 yr 2/N, sapric; peat; wet; massive. Iron hydroxide (?) concretions abundant; rounded fine and medium gravel skeleton 70%, top of gravel clean, sides and bottom have organo-mineral accumulation. Moisture increases with depth, skeleton 80%+, roots few. Lower boundary clear to abrupt, uneven.

AMC 115

Depth	Horizon	
22-26"	B21	Dark brown, 7.5 yr 3/2, silt loam; massive, slightly indurated, breaks to strong, coarse, angular blocky structure; skeleton as above; 1 to 3 inches mineral soil acts as matrix; roots occasional. Lower boundary abrupt, pendant.
26-29+"	B22	Very dark greyish brown to dark brown, 10 yr 3/2-3/3, gravelly silt, skeleton 70%; wet; oozing water. Darker colors appear to be organic coatings.

SOIL GROUP bh
(Sandy phase)

AMC 122 | Cloudy | Amchitka Island

Vegetation: Empetrum nigrum; Cladonia pacifica; Calamagrostis nu.tkaensis; Salex sp. coverage 100%.

Topography: Uniform east-facing slope (15°) downslope from deflation crest.

Micro relief: Hummocks to 15 inches with slight tendency to contour orientation.

Drainage: Well drained.

Remarks: Profile typical of physiographic segments IV through VI. Entire profile may be classified as mineral.

Depth	Horizon	
2-0"		Mat of living vegetation.
0-2+	Oa1	Very dark brown, 10 yr 2/2, sandy sapric peat; moist; massive to slightly friable; very weak fine granular structure; roots abundant. Lower boundary clear, even.
2-6½"	Oa2	Strong brown, 7.5 yr 3/4, sandy sapric peat; massive to somewhat friable; weak, medium fine granular structure; roots abundant. Lower boundary clear, even.

AMC 122

Depth	Horizon	
6½-9"	Oa3	Dark reddish brown, 5 yr 2/2 sandy sapric peat; massive; slightly brittle; crushes to strong coarse angular blocky structure; roots plentiful. Lower boundary clear, even.
9-11½"	Oa4	Dark brown, .5 yr 3/2, sapric, massive to slightly friable; breaks to strong, medium granular structure; roots plentiful. Lower boundary clear even.
11½-14"	Oa5	Dark brown, 7.5 yr 3/2, Sapric, massive, slightly brittle; somewhat platy; crushes to moderate, medium to coarse angular and subangular blocky units; ped interior dark yellowish brown 10 yr 3/4; roots common. Lower boundary clear, somewhat uneven.
14-19"	Oa6(?)	Very dark greyish brown to dark brown, 10 yr 3/2-3/3 organic silt loam; massive; moderately brittle; coarsely platy; crushes to very strong, very coarse angular blocky; fine roots common. Lower boundary clear, even.
19-25"	Oa7(?)	Black, 10 yr 2/1, loamy sapric peat; massive; moderately brittle; crushes to very strong, coarse angular to subangular blocky structure; very weakly platy; skeleton 30% increasing to

AMC 122

Depth	Horizon	
19-25" (continued)	Oa7(?)	50+% below 21 inches; skeleton clean; roots plentiful. Lower boundary somewhat uneven.
25-29"	B12	Dark brown, 10 yr 3/3 sandy loam; massive; moist; slightly brittle; breaks to strong medium to fine angular blocky; skeleton 15%, approximately 1 inch; roots few. Lower boundary gradual.
29-33"	B2	Dark brown, 10 yr 3/3, (ped coatings very dark greyish brown 10 yr 3/2); gravelly loam; massive; slightly peaty; brittle; breaks to strong, coarse to medium angular blocky structure; skeleton 60%; roots occasional. Lower boundary clear, uneven.
33-35+"	B23	Dark brown to dark yellowish brown, 10 yr 4/3--4/4, gravelly sandy loam; massive; moist; slightly brittle, breaks to strong, medium angular blocky units. Skeleton 20%. Occasional smears or patches of very dark greyish brown 10 yr. 3/2 loam (mixing); value and croma increase to yellowish brown 10 yr 5/6 at 34 inches.

SOIL GROUP c

AMC 60 | Amchitka Island, 1967

Vegetation:	Empetrum n., Lupinus n., scattered Carex sp., and Thamnolia vermicularis.
Topography:	Near crest position, slope angle 5°.
Microrelief:	Few scattered hummocks, 2-5 inches to smooth; occasional eroded areas (CE).
Drainage:	Well drained.

Depth	Horizon	
0-2"	A1	Very dark brown 10 yr. 2/2; silt loam, high in organic matter; very moist; crumbles easily; scattered large rocks 5" ± 10%; roots abundant. Lower boundary clear to gradual.
2-4"	A12	Very dark brown 10 yr. 2/2 silt loam with some fine to medium sand; somewhat loose and friable; moist; breaks to weak, coarse aggregates; roots abundant; scattered large rocks as above; lower boundary clear, even.
4-7"	B1	Dark brown 10 yr. 3/2 organo silt loam or silty clay loam; massive; moist; breaks to moderate, coarse angular blocky and aggregate structure; roots abundant; lower boundary abrupt, uneven.

AMC 60

Depth	Horizon	
7-12"	B12	Dark brown coarse sandy loam 7.5 yr. 3/2; strong, coarse aggregates; fine roots abundant; lower boundary clear, uneven.
12-17 "	B22	Dark brown 10 yr. 3/3 to yellowish brown 10 yr. 5/4 appearing as a coating on peds; loamy coarse sand and gravel; massive; structure less to very weak, fine subangular blocky or (aggregate of sand grains); fine roots common; lower boundary clear to abrupt, uneven.
17-22+"	C	Pale brown 10 yr. 6/3 moderately well indurated gravelly sand with coatings of 5 yr. 3/2-3/3 very dark greyish brown to dark brown and occasional flecks of 7.5 yr. 6/6 reddish yellow; skeleton 90%; many fine gravel fragments completely decomposed; much of skeleton composed of volcanic rocks 3+"; roots absent.

No iron stain on under side of rocks and no clay coats observed.

SOIL GROUP ce
(Eroded Phase)

AMC 54 | Partly Cloudy | Amchitka Island, 1967

Vegetation: Mostly isolated plants or small groups, *Lupinus n.*

Topography: Crest position, slope angle 1°.

Microrelief: 95+% lag gravel 1-3#, scattered boulders, very weakly developed polygonal cells.

Drainage: Well-drained.

Depth	Horizon	
0-1"	B2P*	Olive brown 2.5 yr. 4/4 gravelly sandy loam; loose; fragments range between 1/4 - 1/2"; roots absent; lower boundary clear.
1-3"	B2P	Light olive brown 2.5 yr. 5/4 sandy gravelly loam; massive; breaks to single grain or coarse aggregates; somewhat visicular; roots absent; Lower boundary clear.
3-5"	B22	Light olive brown 2.5 yr. 5/4 medium to coarse sandy loam; massive; moderate to strong, coarse angular blocky structure; roots absent; Lower boundary clear.
5-8"	B3	Yellowish brown 10 yr. 5/4-5/6 loamy coarse to medium sand; loose; single grain to weak, fine to medium aggregates; roots absent. Lower boundary clear.

* disturbed layer or horizon

AMC 54

Depth	Horizon	
8-14"	C1i	Light olive brown 2.5 yr. 5/4 loamy coarse to medium sand; massive; slightly indurated; breaks with ease to single grain or displays a gross platyness; roots absent; lower boundary clear.
14-20+"	C2i	Pale brown 10 yr. 6/3 coarse to medium sand; moderately well developed platyness 1/4-1/8" thick; moderately well indurated; breaks to single grained; few large rocks at depth, less than 5%.

SOIL GROUP c-ce

AMC 105 | Fog | Amchitka Island, 1968

Vegetation: Scattered Carex sp., Empetrum nigrum; Salix sp; Thamnolia vermicularis Coverage at site 40%; coverage of general area ranges between 10 and 40%.

Topography: Crest area, lag gravel surface. Slope angle 0°.

Microrelief: Lag, boulder size averages 8" (range 3-12"). Occasional vegetation hummocks 3-12".

Drainage: Well-drained.

Depth	Horizon	
0-2"	321	Very dark greyish brown, 10 yr 3/2, medium to coarse loamy sand; moist; massive to slightly friable. In depressions and under sandy loam with abundant roots. Organic matter less than 10%. Skeleton 10% in 1 to 3" range. Roots common. No reaction to HCl. Lower boundary clear, uneven.
2-5"	322	Dark brown 10 yr 3/3 loamy fine sand; massive, moist, breaks to weak, coarse subangular blocky units. Very coarse sand and granular material less than 20%; pebble skeleton less than 15%. Roots common; Lower boundary clear to abrupt, uneven.

AMC 105

Depth	Horizon	
5-10"	B23	Dark brown to dark yellowish brown 10 yr 3/3--3/4 fine to very fine loamy sand; very moist. Granule material 10-15%; skeleton 80%. Loamy sand and granules act as matrix in skeleton. Clay coats on skeleton; granules are moderately to strongly weathered; fine roots common; Lower boundary abrupt, uneven. Active horizon in frost hearing.
10-15"	C1	Dark brown 10 yr. 4/3, fine to very fine loamy sand, more dry than above horizon; massive. Soil acts as matrix in coarse skeleton (90%) fragments in 1 to 4 range. Some void space. Clay coats on upper surface of skeleton. Roots absent; lower boundary gradual.
15+"	R	Fractured bedrock, approximately 4% void space; small amounts of loamy fine sand in voids. Roots absent.

SOIL GROUP ce

AMC 128 | Partly Cloudy | Amchitka Island, 1968

Vegetation: Lupinus nootkatensis Empetrum nigrum; coverage 25%; 75% lag gravel, 2 to 5 inches.

Topography: Crest position, physiographic segment VI, slope angle 0°.

Microrelief: Small isolated sand dunes some large dunes, discontinuous, contour oriented dunes 12 to 15 inches facing southeast.

Drainage: Moderately well drained.

Depth	Horizon	
1-0"		Surface lag gravel (one fragment deep)
0-3"	B12	Very dark greyish brown to dark brown, 10 yr 3/2-3/3, gravelly sandy loam; moist; massive; highly visicular. Visicules coated; breaks to very strong, very coarse angular blocky units, fine roots common. Lower boundary clear, uneven.
3-6"	B13	Brown to dark yellowish brown, 10 yr 4/3-4/4, Loam; moist; massive; breaks to very strong to strong coarse subangular blocky units; moderately visicular; fine roots common. Lower boundary clear, uneven.

AMC 128

Depth	Horizon	
6-10"	B2	Strong brown, 7.5 yr 5/6, Loam; massive to somewhat friable; breaks to strong, coarse angular blocky units; completely weathered granules common; fine roots common. Lower boundary clear to abrupt, even.
10-13"	B21	Yellowish brown, 10 yr. 5/4, 5/6, fine gravelly sandy loam; moist; massive; breaks to very strong, very coarse angular blocky units; peds have weak clay coatings; moderately platy; weakly vesicular; roots absent. Lower boundary clear, even.
13-17+"	B22	Yellowish brown 10 yr 5/6 coarse gravelly silt loam, (gravel fragments 1 to 2 inches), smaller fragments completely weathered; massive; platy; breaks to very strong, coarse angular blocky units with weak coats of silt; lower surfaces of skeleton have iron coatings.

SOIL GROUP h

AMC 102	Cloudy-fog	Amchitka Island, 1968.

Vegetation:	*Empetrum nigrum*, *Thamnolia* *Lupinus sp.* and *Salix sp.*
Topography:	Felsenmeer covered upland, approximately 30 feet downslope from bedrock outcrop. Slope angle 5°.
Microrelief:	Lag boulders and cobbles. Relief to 6 inches.
Drainage:	Well-drained.

Depth	Horizon	
1-0"		Mat of vegetation between boulders.
0-4"	Oal	Dark brown 7.5 yr. 3/2 sapric; contains some mineral material; massive, somewhat brittle, breaks to weak moderate angular blocky structure; skeleton 50-60% in range 2--5". Larger fragments have salt encrustations. Mineral material fills in around skeleton. Roots abundant. Lower boundary gradual.
4-10"	A1	Dark brown 7.5 yr 3/2 sapric-mineral. Massive, breaks to weak, medium, coarse angular blocky and platy units. Skeleton 80% in the 3-5" range. Void space 30%. Salt encrustations common above 7", absent below. Void space below 7" is less than 10%. Skeleton surfaces

AMC 102

Depth	Horizon	
4-10"	A1	clear, roots plentiful and concentrated in
(continued)		voids. Lower boundary clear, uneven.
10-13½"	B2	Dark yellowish brown 10 yr 3/4 very fine sandy loam; organic matter high; massive; crushes to moderate, medium angular blocky to weakly platy structure. Skeleton 15-20%; voids absent; roots common; Lower boundary clear, uneven.
13½-18½"	B22	Dark brown 10 yr 3/3 sandy loam; massive, breaks to moderate, medium, coarse subangular blocky structure to somewhat friable and granular. Very coarse sand and granules 30% of horizon. Roots few; Lower boundary abrupt, uneven.
18½-22+"	B3	Dark yellowish brown 10 yr 4/4 fine to medium sandy loam. Little organic matter; massive, breaks to moderate, medium, subangular blocky and granular. Skeleton 75% in 1 to 3" range. No voids. Roots absent.

SOIL GROUP e

AMC 73 Cloudy Amchitka Island, 1967.

Vegetation: *Elymus arenarius*, vetch, grass.

Topography: Bluff area along noth coast 7° (variable); stabilized sand dune

Microrelief: Slightly hummocky under vegetation

Drainage: Well drained

Depth	Horizon	
5-0"	01	Largely dead and somewhat decomposed grasses and *Elymus* a. Lower boundary abrupt.
0-3"	A1	Dark reddish brown 5 yr. 2/2 loamy medium sand; high in organic matter; somewhat massive to structureless; roots abundant; lower boundary clear.
3-6"	A12	Very dark brown 10 yr. 2/2 loamy medium sand; massive; structureless; lower boundary gradual.
6-10"	B3	Black to very dark brown slightly loamy sand 10 yr. 2/N-2/2; loose; moist; single grained to having a very weak, coarse aggregate structure; roots abundant; lower boundary clear.
10-30+"	C1&2	Black to very dark brown 10 yr. 2/N-2/2 sand; moist; single grained; roots few.

APPENDIX B

Pertinent Chemical and Physical Data for representatives of major soil groups

SELECTED CHEMICAL ANALYSES

SOIL GROUP a_1, AMC-79

Horizon	Depth	pH 1:1 (H_2O)	%Wt.Loss on ignition	Organic Carbon %	Exchangeable Cations meq./100 g.					Sum Cations Meq/100g.	Sum Bases Meq/100g.	Base Saturation %
					H	Ca	Mg	Na	K			
Oa1	1-3	5.0	89.7	41.7	48.2	17.4	23.9	3.9	2.08	95.5	47.3	50
Oe1	3-5	4.7	92.0	48.7	74.1	12.8	17.7	3.3	1.55	109.5	35.4	32
Oi1	8½-11	4.8	84.2	44.9	103.5	7.2	9.4	2.6	0.44	123.1	19.6	16
Oi2	11-21½	4.7	94.2	53.9	131.4	8.2	8.8	2.2	0.26	150.9	19.5	13
Oi3	21-23	4.8	83.8	42.9	119.6	10.2	8.3	2.1	0.14	140.3	20.7	15
Oe2	23-24	4.9	17.4	9.1	36.0	1.4	1.4	0.5	0.02	39.3	3.3	8
Oi4	24-28½	5.0	86.2	44.0	98.9	8.8	6.9	1.9	0.10	116.6	17.7	15
Oi5	28½-35	5.1	76.7	41.1	80.6	8.5	6.9	2.2	0.11	98.3	17.7	18

SELECTED CHEMICAL ANALYSES
Soil group a_2

Profile	Horizon	Depth in Inches	pH* H_2O	pH KCl	Organic Carbon %	Wt. Loss/ Ignition	Exchangeable Cations meq/100g* H	Ca	Mg	K	Na	Sum Bases Meq/100g.	Base Saturation
AMC 63	Oe1	1-4	4.3	3.8	46.5	91.6	60.0	3.8	8.2	1.85	2.40	76.3	19
	Oe2	4-10	4.5	3.9	46.3	92.1	52.0	2.1	4.1	0.45	2.03	60.7	11
	u	10-11[2]	4.7	4.3	11.8	21.8	31.2	0.4	1.3	0.14	1.15	33.3	--
	Oi1	11-18	4.5	4.1	48.6	89.3	41.8	2.1	4.1	0.29	1.72	50.0	13
	Oe3	18-22	4.6	4.0	51.0	92.5	41.6	3.2	5.2	0.29	1.84	52.1	17
	Oe4	22-42	4.6	4.3	45.6	82.4	31.4	2.8	3.6	0.15	1.25	39.2	17
	u	27-30[2]	5.2	4.7	13.5	25.8	43.2	1.1	0.7	0.08	0.61	45.7	--
	Oi3	48-54	5.0	4.4	38.9	70.3	42.4	2.3	2.9	0.11	0.97	48.7	11
	Oi4	54-60	4.7	4.3	46.7	84.1	29.6	2.7	3.1	0.10	0.59	36.1	17
	Oe6	60-70	5.0	4.5	49.8	90.9	33.3	7.1	4.3	0.14	1.00	45.8	25

* Values corrected for moisture

1 Sample depleted

2 Ash layer

SELECTED MECHANICAL ANALYSES
Soil group b

Particle size distribution in mm %

Profile	Horizon	Depth	VCS*	CS	MS	FS	VFS	Total Sand	2-5	2-20	20-50	Total Silt 2-50	0.2	0.2-2	Total Clay 2	Texture Class
AMC	Oa1	2-4	7.3	8.7	3.9	6.7	8.3	34.9	5.4	15.7	38.7	54.4	6.8	3.9	10.7	SL
104	Oa2	4-9	12.6	12.5	5.1	10.8	8.9	49.9	4.0	15.4	24.8	40.2	5.0	4.9	9.9	L
Sandy	A3	9-14	8.9	10.6	5.8	11.9	10.1	47.3	4.0	16.4	24.7	41.1	3.1	8.5	11.6	L
Phase	A31	14-16	0.7	3.6	14.5	19.8	6.2	44.8	2.9	12.5	28.5	41.0	4.0	10.2	14.2	L
	A32	16-18	1.8	6.4	4.8	13.8	10.7	37.5	6.2	21.6	27.3	48.9	3.4	10.2	13.6	L
	B1	18-21	1.4	6.3	5.2	12.4	11.4	36.7	5.5	18.5	30.9	49.4	3.2	10.7	13.9	SL
	B12	21-25	1.6	6.8	6.5	17.0	12.2	44.1	6.6	21.7	19.7	41.4	3.6	10.9	14.5	L
	B22	25-29	4.6	8.0	6.0	17.2	14.1	49.9	6.2	26.8	9.9	36.7	2.6	10.8	13.4	L
	B23	29-33+	18.0	14.1	5.8	12.1	9.9	59.9	4.8	17.6	12.2	29.9	3.5	6.7	10.2	Sal
AMC	B2	22-26	2.9	3.2	1.8	7.2	13.6	28.7	12.1	32.9	16.0	48.9	0.7	21.7	22.4	L
108 Modal	B23	26-31	8.4	7.4	4.2	9.0	11.3	40.3	8.4	29.8	14.1	43.9	0.2	15.6	15.8	L
AMC	u	12-15	0.3	1.1	1.8	14.0	35.0	52.2	---	28.4	13.4	41.8	0.7	5.3	6.0	--
59	B2	27-29	3.6	9.5	8.8	21.6	16.2	59.7	---	24.7	9.3	34.1	0.1	6.1	6.2	--

* VCS = Very coarse sand
** SL = Silt Loam; L = Loam; Sal = Sandy Loam

SELECTED CHEMICAL ANALYSES
soil group b

Profile	Horizon	Depth in Inches	pH KCL	pH H_2O	% Organic Carbon	% Wt. Loss on Ignition	Exchangeable cations Fe_2O_3	H (Meqs./100 Gms.)	CA	MG	NA	K	Sum of Cations	Sum of Bases	% Base Saturation
AMC	A3	9-14	4.5	5.6	6.4	12.6	---	----	---	---	----	----	----	---	--
104*	A31	14-16	4.8	5.7	10.1	25.3	---	----	---	---	----	----	----	---	--
Sandy	A32	16-18	4.8	5.7	7.8	21.1	---	----	---	---	----	----	----	---	--
Phase	B1	18-21	4.8	5.6	8.0	21.1	---	----	---	---	----	----	----	---	--
	B12	21-25	4.9	5.4	7.6	18.1	5.1	49.3	3.1	5.1	0.35	0.11	57.9	8.6	15
	B22	25-29	4.7	5.2	6.4	14.8	5.8	54.3	4.2	5.7	0.39	0.15	64.7	10.4	16
	B23	29-33+	4.8	5.2	4.9	9.8	2.1	45.6	3.4	5.8	0.30	0.10	55.2	9.6	17
	Oe1	0-2	4.3	5.6	35.8	89.6	---	----	---	---	----	----	----	---	--
	u	5½-6½	4.3	5.1	9.5	18.7	---	----	---	---	----	----	----	---	--
AMC	Oa3	6½-8	4.5	5.4	31.4	68.3	---	----	---	---	----	----	----	---	--
108*	Oa4	8-10	4.5	5.5	30.4	66.7	---	----	---	---	----	----	----	---	--
Modal	u	11-13	4.8	5.4	9.2	20.6	---	----	---	---	----	----	----	---	--
	Oa6	13-14½	4.7	5.4	19.1	44.4	---	----	---	---	----	----	----	---	--
	Oa7	14½-18	4.7	5.4	20.5	50.6	---	----	---	---	----	----	----	---	--
	Oa8	18-22	4.6	5.3			---	----	---	---	----	----	----	---	--
	B2	22-26	4.8	5.5	7.5	20.1	5.1	66.2	6.2	6.4	0.64	0.03	79.5	13.3	17
	B23	26-31+	4.8	5.4	3.5	12.3	1.6	24.1	5.3	0.75	0.03	0.03	90.6	30.2	33
	Oe1	0-2	3.8	4.2	41.6	80.4	---	57.7	5.1	8.3	1.32	1.77	74.2	---	22
AMC	Oa1	2-6	4.0	4.3	39.0	73.5	---	34.3	1.3	3.9	0.91	1.39	41.8	---	18
59	u	7-8	4.4	4.8	11.6	20.9	---	37.4	0.2	1.0	0.35	0.27	39.2	---	5
	Oa3	8-12	4.4	5.0	30.4	55.8	---	48.9	0.3	1.5	0.60	0.65	51.9	---	6
	u	12-15	4.6	4.7	8.5	19.4	---	38.3	0.1	0.3	0.23	0.19	39.1	---	2
	Oa4	15-25	4.8	4.8	10.8	24.8	---	37.8	0.0	0.6	0.34	0.24	38.9	---	3
	Oa5	25-27	4.6	4.8	31.5	57.3	---	38.8	0.0	1.4	0.56	0.21	41.0	---	5
	B2	27+	4.6	5.1	3.1	10.0	---	34.8	0.4	0.7	0.58	0.50	37.0	---	6

* Samples run at field moisture; values corrected.

SELECTED MECHANICAL ANALYSES
soil group bh

Particle size Distribution in mm %

Profile	Horizon	Depth	VCS*	CS	MS	FS	VFS	Total Sand	2-5	2-20	20-50	Total Silt 2-50	0.2	0.2-2	Total Clay 2	Texture Class
AMC	B2	16-19	3.9	8.2	5.4	12.4	15.4	45.3	---	31.8	12.5	44.3	0.3	10.1	10.4	L*
64	B23	19-25+	8.5	15.0	8.2	13.6	11.3	56.6	---	28.9	10.9	39.8	0.2	3.4	3.6	Sal
AMC	B22	12-16	13.6	9.8	9.5	18.0	6.2	57.1	7.7	16.5	11.5	28.0	5.1	9.8	14.9	Sal
114	B23	16-19½	10.4	7.8	9.6	20.4	8.0	56.2	8.6	22.8	3.2	26.0	0.2	17.6	17.8	Sal
		19½-23+	5.0	7.2	9.6	21.7	10.0	53.5	7.6	24.3	6.8	31.1	1.2	14.2	15.4	L
AMC	Oa7	15-22	0.2	0.1	0.1	0.6	0.0	1.0	4.1	13.1	81.4	94.4	0.1	3.6	4.6	S
115	B21	22-26	5.4	2.5	1.1	2.0	2.4	13.4	6.1	17.2	61.2	78.4	0.8	7.4	8.2	SL
	B22	26-29+	1.7	0.6	0.2	0.4	0.8	3.7	7.0	22.7	69.2	91.9	0.1	4.3	4.4	S
AMC	Oa1	0-2	0.6	3.0	7.1	17.0	8.9	36.6	5.4	19.2	34.8	54.0	5.4	5.0	9.4	SL
122	Oa2	2-6½	0.2	2.3	5.2	12.8	8.8	29.3	3.4	18.6	38.1	56.7	4.2	9.8	14.0	SL
	Oa3	6½-9	0.3	0.7	3.1	17.0	10.8	31.9	4.4	18.2	35.3	53.5	3.6	11.0	14.6	SL
	Oa4	9-11½	0.4	0.6	0.5	8.3	18.0	27.8	5.6	20.9	37.3	58.2	0.8	13.2	14.0	SL
	Oa5	11½-14	0.8	1.2	1.4	6.9	12.8	23.1	8.4	20.8	40.3	61.1	1.3	14.5	15.8	SL
	Oa6	14-19	2.4	3.3	2.2	6.6	11.2	25.7	7.6	22.7	33.1	55.8	1.6	16.9	18.5	SL
	Oa7	19-25	8.9	7.8	3.2	5.5	7.2	32.6	7.6	18.2	30.8	49.0	2.0	16.4	18.4	L
	B12	25-29	13.6	13.3	6.8	12.0	9.2	54.9	5.8	14.3	14.4	28.7	2.1	14.3	16.4	Sal
	B2	29-33	12.6	10.2	5.1	11.9	8.4	48.2	5.9	17.5	17.4	34.9	0.6	16.3	16.9	L
	B23	33-35+	9.2	9.6	5.3	10.2	12.4	46.7	3.8	25.9	13.8	39.7	1.3	12.3	13.6	L

* VCS = Very coarse sand

** SL = Silt Loam; L = Loam; Sal = Sandy Loam

SELECTED CHEMICAL ANALYSES
Soil group bh

Profile	Horizon	Depth	pH		Organic	%Wt Loss/		Meqs./100 Gms.					Sum of	Sum of	% Base
			H_2O	KCl	Carbon%	Ignition	Fe_2O_3	H	Ca	Mg	Na	K	Cations	Bases	Saturation
AMC 64*	Oa1	0-1	4.8	3.8	29.6	55.1	---	54.7	4.4	8.2	1.46	1.88	70.6	---	23
	Oa2	1-2	4.3	4.1	20.0	39.7	---	61.2	1.5	4.7	0.56	1.27	69.2	---	12
	Oa2	2-4	4.6	4.2	19.4	38.0	---	70.5	0.8	3.2	0.47	0.70	75.7	---	7
	Oa3	4-8	4.9	4.5	19.4	38.6	---	92.6	0.4	1.3	0.54	0.63	95.5	---	3
	Oa4	8-12	5.1	4.6	18.8	38.1	---	66.8	0.5	1.8	0.54	0.72	70.4	---	5
	Oa5	12-16	4.9	4.6	11.9	28.7	---	54.9	0.0	1.3	0.65	1.64	58.5	---	6
	B2	16-19	5.0	4.6	6.6	16.2	---	49.4	0.1	0.7	0.80	1.84	52.8	---	6
	B23	19-25+	4.7	4.8	1.5	9.0	---	33.8	0.3	1.1	0.87	2.34	38.4	---	12
AMC 114*	Oa1	1½-4	5.5	4.5	14.3	35.2	---	----	---	---	----	----	----	---	--
	Oa2	4-5½	5.5	4.5	17.3	36.1	---	----	---	---	----	----	----	---	--
	Oa3	5½-12	5.5	4.6	18.9	46.4	---	----	---	---	----	----	----	---	--
	B22	12-16	5.4	4.8	4.2	9.1	1.7	41.1	4.3	4.5	0.74	0.38	51.0	9.9	19
	B23	16-19½	5.4	4.9	3.4	9.6	1.5	35.3	4.0	4.0	0.65	0.36	44.3	9.0	20
	---	19½-23+	5.5	5.0	1.8	6.9	1.8	23.5	4.0	3.8	0.75	0.43	32.5	9.0	28

* Samples run at field moisture, values corrected.

SELECTED CHEMICAL ANALYSES (Continued from preceding page)
Soil group bh

Profile	Horizon	Depth	pH		Organic	%Wt. Loss/		Meqs./100 Gms.					Sum of	Sum of	%Base Sa
			KCl	H_2O	Carbon%	Ignition	Fe_2O_3	H	Ca	Mg	Na	K	Cations	Bases	turation
AMC	Oa1	0-2	3.7	5.1	29.9	76.0	---	----	---	---	----	----	----	----	--
115*	Oa2-3	2-6	4.1	5.1	14.3	36.1	---	----	---	---	----	----	----	----	--
	Oa4	6-7	4.3	5.4	12.4	23.9	---	----	---	---	----	----	----	----	--
	---	7-10	4.4	5.4	19.2	43.2	---	----	---	---	----	----	----	----	--
	Oa5	10-12	4.7	5.4	12.7	29.8	---	----	---	---	----	----	----	----	--
	Oa6	12-15	4.7	5.5	17.5	38.9	---	----	---	---	----	----	----	----	--
	Oa7	15-22	4.7	5.5	23.5	51.9	2.3	108.5	4.0	8.0	0.68	0.71	121.9	13.4	11
	B21	22-26	4.9	5.4	4.9	11.6	2.5	39.9	3.9	4.0	0.70	0.41	48.9	9.0	18
	B22	26-29+	4.9	5.4	7.5	17.6	2.9	25.2	3.8	5.2	0.71	0.30	35.2	10.0	28
AMC	Oa1	0-2	4.3	5.6	11.7	26.2	---	----	---	---	----	----	----	----	--
122*	Oa2	2-6½	4.7	6.2	12.1	23.5	---	----	---	---	----	----	----	----	--
	Oa3	6½-9	4.9	6.1	11.6	24.7	---	----	---	---	----	----	----	----	--
	Oa4	9-11½	5.0	6.0	10.6	23.8	---	----	---	---	----	----	----	----	--
	Oa5	11½-14	4.8	5.8	~~8.7~~ 9.2	20.4	---	----	---	---	----	----	----	----	--
	Oa6(?)	14-19	4.7	5.7	6.5	18.2	---	----	---	---	----	----	----	----	--
	Oa7(?)	19-25	4.6	5.5	8.7	17.4	---	----	---	---	----	----	----	----	--
	B12	25-29	4.4	5.3	2.0	7.8	---	----	---	---	----	----	----	----	--
	B2	29-33	4.7	5.4	3.4	11.6	3.4	35.9	3.9	5.8	0.44	0.12	46.2	10.3	22
	B23	33-35+	4.8	5.4	2.0	7.7	1.1	27.0	2.1	3.4	0.33	0.09	32.9	5.9	18

* Samples run at field moisture, values corrected.

SELECTED MECHANICAL ANALYSES
Soil Groups c-ce

Particle size Distribution in mm %

Profile	Horizon	Depth	VCS*	CS	MS	FS	VFS	Total Sand	2-5	2-20	20-50	2-50	0.2	0.2-2	2	Texture Class
AMC	AI	0-2	1.3	3.7	3.3	11.7	6.5	26.6	---	22.2	37.1	59.3	5.6	8.5	14.1	LS
60	A12	2-4	1.8	4.1	6.1	16.4	10.6	39.0	---	22.1	24.6	46.7	4.0	10.3	14.3	L
	B1	4-7	7.5	9.5	7.7	15.3	9.6	49.6	---	23.4	14.9	38.3	2.1	10.0	12.1	L
	B12	7-12	8.8	13.0	8.3	17.5	11.4	58.9	---	22.2	10.1	32.3	2.0	6.8	8.8	Sal
	B22	12-17	5.5	15.5	10.1	21.6	14.4	67.0	---	16.5	10.6	27.1	1.4	4.5	5.9	Sal
	C	17-22+	10.2	19.3	9.0	17.3	12.6	68.4	---	17.4	10.0	27.4	1.1	3.1	4.2	Sal
AMC	B2p	1-3	18.5	16.7	8.0	13.5	7.8	64.5	---	21.1	6.0	27.1	1.0	7.4	8.4	Sal
54	B22	3-5	13.0	17.1	7.8	12.8	8.2	59.0	---	23.0	8.8	31.8	1.2	8.0	9.2	Sal
	B3	5-8	17.0	19.9	9.1	14.0	9.0	69.1	---	18.6	6.6	25.2	0.8	4.9	5.7	Sal
	C1i	8-14	19.0	20.3	10.1	15.9	9.4	74.8	---	15.6	5.4	21.0	1.0	3.2	4.2	Sal
	C2i	14-20	16.1	21.4	10.1	15.9	8.8	72.4	---	17.0	5.6	22.6	1.1	3.9	5.0	Sal
AMC	B21	0-2	8.6	7.4	6.1	11.1	16.6	49.8	6.3	28.2	14.1	42.3	0.4	7.5	7.9	L
105	B22	2-5	8.9	11.0	6.2	11.4	12.0	49.5	6.3	26.5	14.1	40.6	0.4	9.5	9.9	L
	B23	5-10	4.3	5.3	5.1	10.9	14.9	40.5	8.0	28.2	22.0	50.2	0.0	9.3	9.3	SL
	C1	10-15	2.4	2.3	2.3	7.0	15.4	29.4	12.2	50.5	12.2	62.7	0.5	7.4	7.9	SL
AMC	B12	0-3	12.9	9.4	5.8	12.4	12.2	52.7	6.6	20.6	15.9	36.5	0.6	10.2	10.8	Sal
128	B13	3-6	7.8	6.9	4.0	10.6	11.3	40.6	8.8	28.3	17.3	45.6	0.8	13.0	13.8	L
	B2	6-10	7.5	8.5	5.0	12.8	13.0	46.8	9.7	29.6	11.9	41.5	1.2	10.5	11.7	L
	B21	10-13	9.4	9.5	5.0	13.2	14.0	51.1	10.1	31.0	9.1	40.1	1.1	7.7	8.8	Sal
	B22	13-17+	4.4	3.0	1.6	6.9	16.0	31.9	15.2	45.3	10.8	56.1	1.0	11.0	12.0	SL

* VCS = Very coarse sand

** SL = Silt Loam; L = Loam; Sal = Sandy Loam

SELECTED CHEMICAL ANALYSES
Soil groups c and ce

Profile	Horizon	Depth in Inches	pH H_2O	pH KCl	Organic Carbon %	% Wt Loss/ Ignition	Fe_2O_3	Exchangeable Cations meq/100g. H	Ca	Mg	Na	K	Sum of Cations	Sum of Bases	Base Saturation
AMC 60	A1	0-2	4.2	3.9	26.5	---	---	53.3	4.0	6.9	1.25	1.12	----	----	--
	A12	2-4	4.5	4.2	14.4	---	---	50.6	1.9	3.7	0.86	0.71	----	----	--
	B1	4-7	5.0	4.5	9.2	---	---	44.8	1.6	2.6	0.57	0.38	----	----	--
	B12	7-12	5.1	4.6	4.1	---	---	32.9	1.1	1.8	0.46	0.33	----	----	--
	B22	12-17	5.5	4.6	2.0	---	---	26.9	0.9	2.1	0.46	0.33	----	----	--
	C	17-22+	5.4	4.5	0.9	---	---	20.2	1.1	2.7	0.57	0.44	----	----	--
AMC 54	B2p	1-3	5.4	5.0	1.1	---	---	14.5	0.1	1.0	0.25	0.23	----	----	--
	B22	3-5	6.4	5.1	0.8	---	---	17.6	0.6	2.3	0.56	0.36	----	----	--
	B3	5-8	6.2	4.9	0.5	---	---	14.6	0.7	1.8	0.52	0.30	----	----	--
	C1i	8-14	6.3	4.9	0.4	---	---	13.8	0.5	1.3	0.51	0.30	----	----	--
	C2i	14-20*	6.5	4.9	0.2	---	---	4.8	0.7	1.8	0.56	0.34	----	----	--
AMC 105	B21	0-2	5.7	5.1	2.3	6.8	1.4	18.6	3.2	6.1	0.23	0.44	28.6	10.0	35
	B22	2-5	6.0	5.2	2.5	8.1	1.2	25.7	4.8	7.5	0.21	0.44	38.7	13.0	34
	B23	5-10	6.2	5.4	2.4	8.3	1.4	30.1	10.9	15.8	0.33	0.68	57.8	27.7	48
	C1	10-15	6.2	5.4	1.3	6.0	1.5	25.3	20.2	48.4	0.82	1.41	96.1	70.8	74
AMC 128	C12	0-3	5.6	5.1	2.8	8.3	1.5	25.9	2.2	4.5	0.19	0.37	33.2	7.3	22
	B13	3-6	5.8	5.3	3.2	11.5	2.5	27.7	6.3	7.7	0.29	0.68	42.7	15.0	35
	B2	6-10	6.2	5.1	1.6	8.7	1.9	33.6	3.6	9.6	0.28	0.63	47.7	14.1	30
	B21	10-13	6.1	5.2	1.3	7.5	2.1	29.3	5.9	10.2	0.29	0.58	46.3	17.0	37
	B22	13-17+	6.4	5.1	0.5	6.5	0.2	30.0	21.3	39.8	0.64	0.98	92.7	62.7	68

* Sample run on field moisture, values corrected.

APPENDIX C

Glossary of Selected Terms

AMC: Designation for Amchitka Island soil samples.

Cirque: A bowl-like hollow, open in front with a steep high rockwall at its back. Former site of a mountain glacier.

Colluvium: Loose and incoherent deposits consisting of both alluvium and transported angular debris.

Fibric: (Farnham, R.S. and Finney, H.R., 1966) or Fibric horizon. The least well-decomposed of the organic horizons. Fibre contents exceed 2/3 of the volume. Fibres are well-preserved and readily identifiable as to botanical origin. Fibres are not easily destroyed by rubbing when wet. Colors range from light yellowish brown through dark brown to reddish brown. Soils having Fibric horizons occur in flat undrained to very poorly drained uplands. Saturated maximum water contents range from 850% to over 3000% on an oven-dry basis. Bulk density values are less than 0.1 gm/cc (6.25 pounds/ft.^{3}).

Hemic: (Farnham, R.S. and Finney, H.R., 1966) or Hemic horizon. An horizon intermediate in degree of decomposition between the less decomposed Fibric horizon and the more decomposed Sapric horizons. These horizons are partly altered, both physically and biochemically. They are dark greyish brown to dark reddish brown in color. Fibre contents average between 1/2 and 2/3 of the volume. Fibres can often be destroyed when the wet organic soil is rubbed. Saturated maximum water contents range from 450-850% on an oven dry basis. Bulk density values range

Hemic: (continued) between 0.1 gm/cc (6.24 pounds/ft.^{3}) and 0.2 gm/cc (12.5 pounds/ft.^{3}).

Karst: A distinctive type of country having caves, underground rivers where surface drainage sinks beneath the surface in rifts and shallow holes.

Knickpoint: Points of abrupt change in the longitudinal profile of stream valleys.

Lag gravel: Residual accumulations of coarser particles from which the finer material has been blown away.

Marine Platform: A smooth bedrock surface produced by wave action.

Névé: Snow that accumulates in mountains and may not melt during the summer.

Pedon: An area of sufficient size to encompass the range of horizon variability of a particular soil.

Periglacial: An environment with a near glacial climate most frequently peripheral to an ice sheet.

Permafrost: Permanently frozen subsoil.

Sapric: (Farnham, R.S. and Finney, H.R., 1966), or Sapric horizon. Highly decomposed organic horizons, which are very dark grey to black in color. They are highly stable, i.e., they change very little physically or chemically with time in comparison to Fibric or Hemic horizons. They occur on sloping well-aerated topography. Fibre contents are less than 1/3 of the volume and saturated, maximum water contents average less than 450% on an oven-dry basis. Bulk density values are greater than

Sapric: (Continued) 0.2 gm/cc (12.5 pounds/$ft.^3$).

Solifluction: The process of slow flowage from higher to lower ground of masses of waste (soil-rock) saturated with water.

Stone Stripe: The alternate stripes of fine and coarse debris on a slope.

Terrace: A level-topped surface, with a steep escarpment composed of soil or rock.

Thermokarst: Settling or caving of the ground due to melting of ground ice (permafrost).

Tor: Rounded remnants of rock which have been scraped by ice.

Toposequence: A succession of topographic elements from plane through slope to crest.

7.5 yr 3/2: Munsell color designation giving chroma, value, and hue. An objective and repeatable characterization of a color.